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Measuring and Analyzing the Liquidity of the Italian Treasury Security Wholesale Secondary Market

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Abstract[°]

Although its importance, only recently the issue of liquidity in Treasury markets has received greater attention. We survey the literature about market liquidity and liquidity measures, and we put forward new measures. The aim is to provide a description of the liquidity of the Italian wholesale secondary market, which we describe thoroughly. We apply a large set of measures on a unique dataset, which gives us a complete view of the market. Even though the market provides an amount of liquidity that fits the market needs, the quality of the order book is low, and despite the presence of a large number of market makers, the degree of competition among them is not very high. Moreover, no clear and general relationship emerges between trading and order book measures. Indeed, even though trading activity is higher for *on-the-run* securities with respect to the *off-the-run* securities, there is not a sharp difference in terms of liquidity of the order book between them. In this case market regulation plays an important role. Finally, we investigate how long it takes for a new issue to become the benchmark for its segment. Our evidence shows that some modifications of the issuance policy in order to have a larger outstanding since the first auction could help securities in gaining earlier their benchmark status, especially in case of 10-year BTPs.

Keywords: Liquidity, liquidity measures, Government securities, market microstructure, benchmark status.

JEL Classification: D49, G12, H63.

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1. Introduction

In Europe, electronic transactions amount to 75 per cent of total trade volume for government securities. Among the wholesale markets, MTS (*Mercato Telematico dei titoli di Stato*) is the leading market in Europe for the electronic trading of fixed income securities. Within the MTS system the weight of Italian securities is prominent. The main aim of the present report is to measure and evaluate the market liquidity of MTS, by using data on the Italian market. Our results are going to cast additional light on an issue that has received limited attention in the literature: exceptions are Albanesi, Rindi (1999), Cheung, de Jong, Rindi (2005), Girardi, Piga (2207), Inoue (1999).

A financial security is liquid if it can be traded in a marked without affecting its price. Despite its relevance, the concept of market liquidity can hardly be pinned down. Actually, it has multidimensional aspects and, consequently, many different measures of markets liquidity are available. The measures available in the literature can be separated in two main groups: Trade measures and order book measures. Trade measures draw on data on actual financial transactions. Order book measures, on the contrary, describe the characteristics of the order book of the proposals of transactions which are available in the market.

MTS markets are an example of quote-driven electronic order book. Therefore, the quality of the order book is particularly relevant. In effect, the quotes on the book are firm and immediately executable. Therefore, the features of the order book and their evolution in time define the amount of liquidity provided by the market makers.

The main comparative advantage of our research is the availability of high frequency data on the whole order book. Our dataset covers transactions and quotes of the Italian medium and long term government bonds being traded on the MTS platforms from January 2004 to December 2006. Our database contains all the “snapshots” between 8:30am and 5.30pm at a five-minute frequency. All the contracts are also available and they include the sign of the trade and the time of the trade. Transactions and quotes are available for both on-the-run and off-the-run securities, where for on-the-run we mean the most recently auctioned security.

Therefore, our preliminary and main aim was the exploitation of the data set and the presentation of a consistent set of indicators and measures, which could give comprehensive description of the most important features of order book and trading data. Drawing on the results of the descriptive, mainly non parametric analysis, in the last part of the paper we try to identify when, in terms of liquidity, an on-the-run security becomes the reference for its maturity segment, i.e. when it becomes a *benchmark*.

Given the peculiarity of our database, we concentrated on the order book measures: We presented a new taxonomy of order book measures and put forward new measures. Order book measures can be classified according to three dimensions: Tightness, depth and breadth. Having compared the performance of a large set of liquidity indicators, we are able to indicate those that give a comprehensive description of the most important features of order book and trading data. Among tightness measures, *best spread* is our preferred indicator. It directly quantifies the cost of most of the transactions on the market, it behaves consistently with the other liquidity indicators and it is the most easily available liquidity indicator. *Steepness*, which is the main indicators of breadth, is crucial to understand how the MTS order book moves during the day and react to market conditions. The peculiar behaviour of steepness help us to figure out why best spread, spread and weighted spread, that is the main measures of tightness, often move in opposite directions. However, steepness is not consistent with the other measures of liquidity. It rises when the market seems to be more liquid. As to the depth of the order book, we have shown that *quote size* does not uniformly spread out on the order book. That is why quote size has to be examined together with indicators of size distribution: *Best size* is the simplest and most easily available. Among multidimensional order book indicators, that is indicators which combine more than one dimension of our taxonomy, *slope*, *market quality index* and *CRT* turn up to be good synthetic indicators of market liquidity. Among them, slope is one of the liquidity measures originally elaborated by us and it combines breadth and depth.

No clear and general relationship emerges between trading and order book measures. Trading measures can be split in two groups: The first group comprises *trading volume*, *trading frequency*, *turnover*. They either show no correlation with order book measures, or are combined with less liquid order book, although they convey crucial information about the working of the market. The second group comprises *trade size* and *price impact coefficients*. They move in the same directions of the other liquidity measures. However, price impact coefficients are not easily computable and are not available on a real-time basis. Interestingly, slope is conceptually close to price impact coefficient, even though the amount of data needed to calculate the latter is much larger than the one needed for the former. As a matter of fact, in our data the empirical values of the two indicators are reciprocally consistent, even though they are not weekly correlated. Slope seems to be a good liquidity indicator.

The comparison of trade size data with best size data shows that the quantity available on the book at the best price seems to be adequate to the revealed trade needs of the market. Most of trading could occur at the best price. However, the analysis of the correlation between size measures and best spread casts new light on the quality of the order book and on the distribution of quote size. When the market becomes more liquid and quote size increases and best spread shrinks, quote size at the best prices falls, the order book becomes steeper and the additional quantities available for trade are placed at the end of the order book. In the end, even though MTS provides an amount of liquidity that fits the market needs, the quality of the order book is low: Most of the quote size is off the best quote; when the number of the market makers increases, the newcomers quoted prices that are far away from the best prices and make the steepness of the order book to jump. These features could be signalling that, despite the presence of a large number of market makers, the degree of competition among them is not very high.

The medium and long term BTPs seem to represent the most liquid segments. The CTZs have a good performance in terms of *best spread*, but they are characterized by a more dispersed book. The 30 year BTPs show performances that are better than expected with respect to the order book measures. On the other hand, trading activity in this segment is still low and only the index linked bonds exhibit lower figures. This latter segment is, not surprisingly, the worst in terms of most of the employed measures.

Trading measures show a sharp difference between on-the-run and off-the-run securities. Given the higher trading activity recorded in the case of the on-the-run securities, a more liquid order book could be expected for those securities. Surprisingly, all the order book measures do not show any significant difference between on-the-run and off-the-run securities. The reasonable explanation of this evidence has to be looked for in the obligations imposed on market makers on the MTS platform and on the monitoring procedures of Specialists by Italian Treasury. As a consequence, the number of market makers in the off-the-run segment is higher than it would have been in the absence of obligations and monitoring, and this keeps down off-the-run spreads. Dealers probably compensate smaller profits on the off-the-run segment with higher profits on the on-the-run one, that is, in the event of no obligations and monitoring on the off-the-run securities, the spreads on the on-the-run segment would probably be smaller than they are at present. Conversely, the spreads on the off-the-run segment would probably be larger than they are at present.

We exploited the new insights about market liquidity in order to understand when a new issued bond acquires the status of benchmark. The empirical evidence shows that the average number of days needed to gain the benchmark status is increasing in the original maturity of the bond and is in general less than 30 working days. This means that the benchmark status is not acquired immediately, but usually we do not need to wait the first reopening, i.e. the second auction. However, in many cases the benchmark status is actually achieved just a few days before the second auction, and it may be the case that the expectation of a new issue has a positive impact on trade. Furthermore, when our definition of benchmark is tightened, i.e. the number of consecutive days of higher trading activity is set at six, the benchmark status is achieved only after the third and even the forth auction. The 10 year BTPs seem to be more sensible to variations in the selection criterion. In the end, some modifications of the issuance policy in order to have a larger outstanding since the first auctions could help securities in gaining their benchmark status, especially in case of 10 year BTPs

The paper is organized as follows: Section 2 presents the microstructure of the MTS markets, section 3 surveys the literature on liquidity measures and definitions, section 4 states our research agenda, elaborates on our dataset, introduces and classify the liquidity measures employed in our analysis, section 5 presents our main empirical results, section 6 analyses the achievement of the benchmark status by on-the-run securities, section 7 estimates the liquidity premium.

2. Liquidity

A financial security is liquid if it can be traded in a marked without affecting its price. The importance of the liquidity of GS markets stems from the fact that it allows market participants to hedge positions in other fixed income securities, to speculate on interest rates and to price correctly other securities such as derivatives on interest rates. Hence, the measurement of liquidity is of relevance to those who transact in the market and to those who monitor and analyze market conditions and developments. In particular, liquidity is a key issue for central bank functions, including the conduct of monetary policy and the maintenance of financial stability. Furthermore, the degree of liquidity of a security plays a role in the determination of the security yield. Therefore, it can relevantly affect the cost of liability management. In particular, government debt management offices are highly concerned about the liquidity of GS markets.

The importance of liquidity in preserving the stability and efficiency of capital markets means that the role of public policy is fundamental. Regulations can help fostering higher-quality markets at little cost. Conversely, public policy can also harm the liquidity of markets. Therefore, the determinants and mechanics of liquidity in these markets deserve great attention. In effect, although in the last decade the major body of literature about market microstructure focused on equity and foreign exchange markets[1], now the strand of literature about liquidity in bond markets is growing in importance and this is also due to the recent availability of high frequency data[2]. Fleming (1997, 2001, and 2003) for US, D'Sousa, Gaa and Yang (2003) for Canada and Cheung, de Jong and Rindi (2005), Girardi and Piga (2007) for the Euro area measure liquidity and order flows in GSM. Fleming and Remolona (1999), Bollerslev, Cai and Song (2000), Balduzzi, Elton, and Green (2001), Green (2004) analyse price formation and liquidity in the US Treasury market by examining the response of prices, trading volume and bid-ask spreads to macroeconomic announcements. Pagano and von Thadden (2004) document the impact of EMU on the European Bond Market in

[1] Madhavan (2000) and Lyons (2001) survey respectively stock and forex markets.
[2] GovPx for US, CanPx for Canada and MTS Time Series for Europe.

terms of markets integration and liquidity, the consequent emergence of the MTS and Eurex markets and they discuss pros and cons of the "Liquidity Pact"[3].

2.1 Definitions

Market liquidity is a concept that turns out to be hard to pin down. Actually, it has multidimensional aspects and many definitions of markets liquidity are available. For instance, a liquid market can be defined as one in which trades can be executed without costs (O'Hara 1995); another definition states that in a liquid market the participants can rapidly execute large-volume transactions with small impact on prices (CGFS 1999). The usual approach (see for instance Kyle 1985) that the market microstructure literature adopts (see for instance Kyle, 1985) is to think liquidity along three possible dimensions: Tightness, depth and resiliency. *Tightness*[4] indicates how far transaction prices diverge from mid market prices (i.e. the cost of providing liquidity), *depth* is the maximal size of a trade for any given bid/ask spread (or the maximum volume of trades without a significant affection of prices) or the amount of orders on the order-books of market makers at a given time and *resiliency* refers to how quickly prices revert to original (or fundamental) levels after a large transaction (i.e. the speed with which price fluctuations resulting from a trade are dissipated). Another commonly used concept is *immediacy*, defined as the speed with which a trade of a given size at a given cost is completed. However, it incorporates elements of the dimensions listed above and, strictly speaking, it is not a separate dimension[5].

2.2 Survey of liquidity measures

The analysis of market liquidity avails itself of different measures, the preference between one and another depending mainly on the goal of the analysis and data availability. Table 2.1 provides a survey of the most conventional measures, the first and the second column give a definition and some comments, the third column reports the expected relation with market liquidity. Moreover, the first column reports, between square brackets, alternative definition for the measure. As a matter of fact, the definition of many variables is often not unique, since the purpose of the analysis or data availability can differ. The measures reviewed in Table 2.1 range from general information about the securities (e.g. issued amount and age) and the market (e.g. number of participants, bid quantity etc.) to more complex indexes (e.g. percentage bid-ask spread, market quality index etc.). The table also permits to group the variables as trading variables, order book variables and other variables.

[3] From a theoretical point of view, Amihud and Mendelson (1986, 1991) and more recently Pastor and Stambaugh (2003) provide a model explaining the role of liquidity in asset pricing and in government bond asset pricing.

[4] Sometimes in literature it is referred to as *width*.

[5] Sources of the definitions are CGFS (1999) and D'Souza and Gaa (2004).

Table 2.1 Liquidity Measures: Definitions and Comments

Definitions	Comments	Expected Relation to Liquidity
issued amount: the size of the issuance (Houweling et al. 2003).	The larger the outstanding stock of publicly issued central government debt, generally the higher the turnover in cash and futures trading. And the higher the turnover, the better the liquidity (McCauley Remolona 2000).	+
age: time from issuance (Houweling et al. 2003).	It is important for instance because of the market segmentation for different asset maturity (Martinez Resano 2005)	-
missing prices: it occurs when the bond did not trade in a given interval of time.	If the price at the end of the day is identical to that of the previous day, it is highly likely the bond did not trade; likewise if there is a missing price (Houweling et al. 2003).	-
bid-ask spread: *quoted*: gap between quoted bid and ask prices, and is observed before an actual transaction takes place (CGFS 1999).[difference between the best bid and the best ask at any time and averaged over all quotes in a day (Goldreich et al., 2005)] *realised*: gap between weighted averages of the bid and ask prices for executed trades over a period of time, using the transaction volumes at each price as the weights (CGFS 1999). *effective*: twice the difference between each transaction price and the mid-quote immediately preceding the transaction (Goldreich et al., 2005 e Chung et al., 2005). [expressed as a percentage of the mid-quote based on the actual transaction price (Dunne et al. 2006)].	A drawback is that bid and offer quotes are good only for limited quantities and periods of time, thus it only measures the cost of executing a single trade of limited size. To allow for comparison between different securities it should be adjusted to take into account duration (Fleming 2003). Wider spreads may also simply reflect that the bond in question is illiquid for structural, as opposed to market structure, reasons (Casey Lannoo 2005). The *effective* spread incorporates the change in the price between when it is quoted and when it is executed (CGFS 1999).	-
percentage quoted spread: the average of the ratio of the quoted bid/ask spread to the bid/ask price midpoint (Bollen Whaley 1998). [using only two-sided quotes (Brandt Kavajecz 2004)]. *percentage effective spread*: dividing the dollar effective spread by the quote midpoint (Chung Kimb 2005)	It illustrates that spreads differ by the level of share price. Trading costs for low price per share stocks are higher.	-
volume weighted average quoted spread: the average of the quoted bid/ask spreads during the day weighted by the proportion of daily trading volume executed while each pair of quotes was in effect (Bollen Whaley 2005).	It is a measure of depth of the limit order book associated to a specific transaction size, it reflects the implicit cost for an immediate transaction of a given size (Cheung et al. 2005). It weights the prevailing quotes by the number of shares traded (as a proportion of total daily trading volume) while the quotes were in effect. Consequently, this	-

	measure of quoted spread is more accurate *a priori* since transactions at the prevailing quotes indicate that prices were "firm." (Boll Whaley 1998)	
trade - weighted effective spread (Chung Kimb 2005)		**-**
price impact of trades: the difference between the effective and realized spreads. (Chung Kimb 2005)		**-**
quote size: the quantity of securities that is explicitly bid for or offered for sale at the posted bid and offer prices (Fleming 2003).	It can underestimate depth because market makers usually do not reveal the full quantity they want to transact (Fleming 2003).	+
best liquidity: the average of the quoted size at the best bid and offer where considering the quotes immediately preceding the transactions (Dunne et al. 2006).		+
total liquidity: the average of the total amount offered and the total amount bid in the best three quotes where only including the quotes immediately preceding the trades (Dunne et al. 2006).		+
quote frequency: the number of non-repeated quotes in a time interval (D'Souza Gaa 2004).	It is a measure of market activity (D'Souza Gaa 2004).	**+?**
trade size: ex-post measure of the quantity of securities that can be traded at the bid or offer price (Fleming 2003).	It is an endogenous measure because it depends on a negotiation that depends on the liquidity of the market (D'Souza Gaa 2004). Higher trade size is usually associated to low transparency (Dunne et al. 2006)	**+?**
bid-side market depth: the difference between bid and mid price, divided by the bid quantity (Favero et al. 2005).		+
ask-side market depth: the difference between mid price and ask price, divided by the ask quantity (Favero et al. 2005).		+
quoted depth: the average of the bid and ask depth per quoted price, both one and two-sided quotes are used in the calculation (Brandt Kavajecz 2004).	A drawback of this estimate, however, is that market makers often do not reveal the full quantities they are willing to transact at a given price, so the measured depth underestimates the true depth (Fleming 2003).	+
cumulative limit order book depth: sum of the depth posted at the three best price points on both the buy and sell side of the limit order book and average the two sides together (Beber et al. 2007).		+
price impact coefficient (Kyle lambda): the slope of the line that relates the price change to trade size and is typically estimated by regressing price changes on net volume for intervals of fixed time (Fleming 2003).	The measure is relevant to those executing large trades or a series of trades (Fleming 2003). One drawback is that, although it necessitates the use of detailed high-frequency data, it is estimated over a longer sample period (weekly or yearly). The estimated price-impact coefficients therefore cannot be used directly in an analysis of intraday market conditions (D'Souza et al. 2003).	**-**
liquidity premium: "liquidity" spread between more	It can be calculated without high-	**-**

and less liquid securities, often calculated as the difference between the yield of an on the-run security and that of an off-the-run security with similar cash flow characteristics (Fleming 2003).	frequency data. Moreover, because the spread reflects both the price of liquidity as well as differences in liquidity between securities, it provides insight into the value of liquidity not provided by the other measures. However, factors besides liquidity can cause on-the-run securities to trade at a premium, confounding the interpretation of the spread. Furthermore, the choice of an off-the-run benchmark against which to compare an on-the-run security can result in considerable estimation error (Fleming 2003).	
trading volume: the total value of securities traded per unit of time (D'Souza Gaa 2004).	It is positively related with price volatility which is negatively related to liquidity (Fleming 2003).	**?**
trading frequency: the number of trades executed within a specified interval, without regard to trade size (Fleming 2003).	It is positively related with price volatility which is negatively related to liquidity (Fleming 2003).	**?**
price volatility	if we assume a constant fundamental level of prices, volatility in prices could reflect bid-ask spread, the market impact of trades and/or the degree of resiliency (CGFS 1999)	**-**
turnover ratio: the ratio of the average trading volume over a given period of time to the outstanding volume of securities (CGFS 1999).	If the government or the central bank take a large portion of marketable securities out of the market, we should account for it (i.e. subtract such holding from the outstanding volume) (Inoue 1999).	**+**
number of market participants in a given time interval		**+**
net trading quantity: the volume of buyer-initiated trades minus the volume of seller-initiated trades over the time interval (D'Souza Gaa 2004). *net trading count*: the number of buyer-initiated trades minus the number of seller-initiated trades over the time interval (D'Souza Gaa 2004).	Those are conventional measures of trading activity (D'Souza Gaa 2004).	**-**
order imbalance: notional value of buys less the notional value of sells each day, divided by the total value of buys and sells (Chordia Sakar 2005).		**?**
market quality index: the average quoted depth divided by the percentage bid-ask spread (Boll Whaley 1998 & Beber et al. 2007).	Index designed to capture the trade-off between quoted bid/ask spread and market depth (Boll Whaley 1998).	**+**
steepness: the average of steepness on each side of the order book. The steepness is the difference between the 3rd worst bid/offer and the best bid/offer expressed as a percentage of the mid-point between these, multiplied by 100 to show it in basis points terms (Dunne et al. 2006).		**-**
Cost of Round Trip trade (CRT): the percentage cost to buy and sell the same number of shares at the same time (a round-trip trade) by submitting market orders (Irvine et al. 2000). Cheung et al. (2005) give a formulation of CRT for	It aggregates the status of the limit order book at any moment in time for a specific transaction size. It measures the ex ante committed liquidity immediately available in the market, complementing	**-**

the bond market.	the effective spread. For a particular trade size, smaller cost indicates a more liquid market (Irvine et al. 2000).	

Note: The question mark indicates that the theoretical relation with liquidity is not univocal.

3. Methodology of the empirical analysis

Given the survey of liquidity measures, in this section we present and explain in detail the measures we employed in the empirical analysis and the methodology we followed.

3.1. Research agenda

Each of the previous liquidity measures describes a particular aspect of the market. They can be separated in two main groups: Trade measures and order book measures. Trade measures draw on data on actual financial transactions. Order book measures, on the contrary, describe the characteristics of the order book of the proposals of transactions which are available in the market. In order to measure market liquidity, both trade measures and order book measures are useful and they complement each other. Furthermore, their relevance in catching the various aspects of market liquidity depends on the microstructure of the market which is under examination.

In the case of MTS market, the quality of the order book is particularly relevant. In effect, the quotes on the book are firm and immediately executable. Therefore, the features of the order book and their evolution in time define the amount of liquidity provided by the market makers. Under this respect, trade measures can be used in order to verify if the liquidity provided by the order book is consistent with the trade needs revealed by the market.

The main comparative advantage of our research is the availability of high frequency data on the whole order book. Despite the relevance of MTS among government securities markets and the huge amount of information contained in the available data, no previous research has given systematic and thorough evidence on MTS order book. Therefore, our preliminary and main aim was the exploitation of the data set and the presentation of a consistent set of indicators and measures, which could give comprehensive description of the most important features of order book and trading data. Drawing on the results of the descriptive, mainly non parametric analysis, in the last part of the present research report we tried to identify the features that make an on-the-run security a benchmark.

In order to describe our data set and to give evidence on MTS liquidity we followed the following steps:

- elaboration of a taxonomy of liquidity measures;
- elaboration of new liquidity measures and indicators that could exploit the richness of our dataset;
- computation of old and new measures and indicators both on high frequency data and on a weekly base;
- selection of the measures and indicators which give the most useful and efficient description of market liquidity. This evaluation was based, first, on univariate analysis and, second, on the correlations between measures and indicators, in order to assess their reciprocal consistency and their reaction with respect to indicators of market conditions, such as price volatility and number of market makers;

- computation of measures and indicators on sub-samples of data in order to assess the robustness of the empirical results. Namely, the dataset was split between on-the-run and off-the-run securities, between hours of trade concentration and rest of the day, between days where auctions of the same security were taking place on the primary market and rest of the days;
- analysis of the correlation coefficients between liquidity measures in order to evaluate their mutual relationships, reciprocal consistency and reaction to market conditions;
- liquidity comparison across securities of different maturity and analysis of the commonality in market liquidity.

3.2. Order book measures: A taxonomy

We classify order book measures according to three dimensions: *Tightness, depth and breadth*. The first dimension is about the distance between the ask and the bid side of the book. Tightness is the dimension whose connection with the meaning of liquidity is the clearest: The closer the two sides, the more liquid the market. A tight order book reduces the cost of successive buy and sell operations on the same security. The second dimension of our taxonomy, depth, deals with the quantity available for trade on each side of the book. The relationship between depth and the concept of liquidity is clear as well: The deeper the order book the more liquid the market. However, in order to gauge market liquidity we need not only the simple measure of the quantity available for trade but also its position in the book. The third dimension of our classification, breadth, measures how wide the order book is. While depth captures the vertical dimension of each side of the order book, by measuring the quantitative relevance of each proposal, breadth catches the corresponding horizontal dimension by measuring the multiplicity, the variety among the proposals: "A broad market has many participants, none of whom is presumed to exert significant market power"[6].

Breath is the dimension of our classification whose relationship with the concept of liquidity is more controversial. According to some authors the narrower the order book, the more liquid a market[7]. In effect, when one side of the order book is as narrow as possible, that is when it is concentrated just in a quote, all the order book depth is available at the best quote and market liquidity is at maximum for that given level of depth. However, as long as the order book is not wholly concentrated on the best quote, the relationship between breadth and liquidity becomes vaguer. A wide order book where the quantity available for trade is mostly concentrated on the best price is more liquid than an order book made of two adjacent prices where the same quantity is mostly concentrated on the second best price. In our understanding breadth has to be combined with depth in order to have a reliable measure of liquidity.

In the following we are going to use our taxonomy in order to present the order book measures that we employed in the empirical analysis[8]. The measures are considered to be either unidimensional, when they evaluate just one of the three dimensions of our taxonomy, or multidimensional, when they are a combination of at least two dimensions. We are going to present, first, the unidimensional measures and, later, the multidimensional ones. All the unidimensional measures are drawn from the wide literature surveyed above. On the contrary, some of the multidimensional measures we are going to present were originally elaborated by us in order to exploit the richness of our dataset.

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[6] See Hasbrouck (2007). The breadth is strictly connected with market thickness, as defined in Roth (2007).

[7] See Dunne, Moore, Portes (2006).

[8] The complete set of the investigated measures includes also *midquote*, *percentage quoted spread*, *quantity weighted bid (ask) skewness*, *quantity weighted bid (ask) kurtosis*. The final set of measures has been worked out after an evaluation of all the measures in terms of univariate and correlations analysis.

Tightness
The tightness of the order book is measured by spreads. We are going to use three different definitions of spread: best spread, spread and weighted spread. *Best spread* is the difference between the best ask price and best bid price[9]. It is the simplest measure of spread and it can be quickly and easily calculated with data that are widely available. However, it takes into account only one price on each side of the book and the quantity available for trade at the best prices could be very small. The whole set of quotes in any snapshot is included in the definitions of *spread* and *weighted spread*[10]. The former is the difference between the simple average of the ask prices and bid prices. The latter is the difference between the weighted averages, where the weights are given by the quantity available for trade at each quote. The last two measures are more complete, but they can not be so quickly and easily calculated as best spread is.

Depth
We employed several measures of depth: Best size, second size, worst size, quote size, average quote size, weighted depth and quote size per participant. All the measures we are going to present hereafter are averages of the corresponding measures on the two sides of the order book. Preliminary analyses showed the perfect symmetry between the two sides. *Quote size* is the total quantity available for trade in the snapshot[11]. Its value does not depend on the position of the quantity in the book. However, the degree of liquidity of a given amount of quantity for trade is strictly related to its position in the book. In order to evaluate the degree of liquidity of a given total amount available for trade we employed three other measures that split the total quote size in three parts according to the position of the quote quantity in the book: *Best size, second size* and *worst size*[12] measure respectively the quantity available at the best price, at the second best price and in the rest of the book. The rational behind this splitting is clear: If an increase of the depth is due to an increase of the quantity available for trade far from the top of the book, then quote size would overstate the actual market liquidity. Hence, a distinction between quote sizes on the top of the book and on the rest of it better captures the real depth of the market.

We also adopted synthetic measures of depth, that is we calculated some statistics of the quantity available for trade that could better captures the liquidity of the order book in each snapshot. *Average quote size* is the average quantity available for trade per quoted price[13]. It measures how dispersed the quote size is among different quotes. The higher the average quote size, the deeper the order book. Average quote size, however, is independent of the position of quote size in the book. This represents a major drawback of the measure. That is why we put forward a new measure: *weighted depth*. Weighted depth is the weighted sum of the quantity available for trade. The weights are inversely related to the position of the quantity in the book. The quantity available at best price, that is best size, has weight equal to one. Any other quantity in the book has smaller weight and the weight is decreasing with the distance between best price and the price corresponding to the given quantity. Finally, *quote size per market participants* is calculated by averaging the quantity available for trade. The average, however, is not taken on the set of different prices quoted, as in the case of average quote size, but on the set of market makers who expose a double quote in each snapshot. Therefore, it measures the average quantity exposed by each market participant.

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[9] Appendix B provides the analytical formulation of the complete set of the employed measures. Best spread matches with the quoted bid-ask spread in Goldredich (2005).
[10] Spread and weighted spread match with the quoted bid-ask spread in CGFS (1999).
[11] Quote size matches the quote size in Fleming (2003) and it is close to both total liquidity in Dunne et al. (2006) and cumulative order book in Berber et al. (2006).
[12] Best liquidity matches with the best liquidity in Dunne et al. (2006). Second and worst size are not present in the papers we surveyed.
[13] Average quote size matches quoted depth in Brandt and Kavajecz (2004).

Breadth
We employed only one measure of breadth: *Steepness*[14]. *Steepness* is the absolute difference between the best and the worst quote, scaled on the mid-point between the two. As we argued above, breath is the dimension of our classification whose relationship with the concept of liquidity is more controversial. In the following section we will report summary statistics on steepness and we will evaluate if it actually shows a pattern of variability across time which is consistent with the patter shown by other measures whose relationship with market liquidity is unambiguous.

Multidimensional measures
In order to overcome the ambiguity of steepness as a measure of market liquidity we developped three new measures of liquidity: S*lope, DS* and *DSS*. They are multidimensional measures because they draw on two dimensions of our taxonomy, namely, depth and breadth. By combining breadth with depth we were able to elaborate new indexes whose relationship with market liquidity we expect to be clear-cut. *Slope* is the ratio between the absolute difference between the best and the worst quote and the difference between quote size and best size. Geometrically, when we represent quoted prices on the vertical axis and the corresponding cumulative quantities on the horizontale axis, slope is the gradient of the linear interpolation between two points whose coordinates are best price and best size, on one hand, and worst price and total size, on the other hand. As long as the scatter diagram of quoted prices and corresponding cumulative quantities is concentrated around the interpolation line previously defined, slope measures the increase in marginal quoted price a dealer has to bear for trading € 100 mln, additional to the best size[15]. As a consequence, the relationship between slope and market liquidity should be transparent: The higher the slope, the lower the liquidity.

DS is a measure very similar to slope. The differential impact of trade on marginal quoted price, however, is not computed on the basis of a linear interpolation between two points. DS is the regression coefficient of the regression of quoted prices on corresponding cumulative quantities. Obviously, the connection between DS and market liquidity is the same as the one between slope and liquidity: The smaller DS, the more liquid the market.

DSS is the estimate of another regression coefficient. It is based on *deep spread*. For each cumulative quantity in the order book deep spread gives the corresponding maginal bid-ask spread. In other words, when the cumulative quantity on the bid side of the order book has a corresponding cumulative quantity on ask side, we compute the marginal spread insisting on that quantity. Hence, we measure the relationship between changes in the quantities and changes in the marginal spread by regressing the deep spread on the corresponding cumulative quantity. DSS measures the increase in marginal spread that a dealer has to bear for an additional purchase and sale of the security. Conceptually, it is very close to DS and slope and it has the same relationship with market liquidity.

Another interesting multidimensional measure is *market quality index*[16]. It combines the same two dimensions as DSS: tightness and depth. It is computed by taking the ratio between average quote size and spread scaled on the mid price. It measures the average quote quantity per percentage point of spread. The higher is the index, the higher the liquidity. For reasons that will be clear later, we employed a modified specification of the measure as well. In *Market quality index 2* quote size substitute for average quote size at the numerator of the index.

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[14] Steepness matches with steepness in Dunne et al. (2006).
[15] Slope is analogous to the price impact coefficient, i.e. the Kyle lambda, in Fleming (2003). However, slope is an order book measure, on the contrary price impact coefficient is calculated on trade data.
[16] Market quality index matches with market quality index in Boll and Whaley (1998) and in Berber et al. (2006).

Finally, following Cheung et al. (2005) we adapted to the bond market the Irvine et al. (2000) percentage *cost of the round trip*. This is the weighted average price at which a double order of sell and buy of size *L* could be immediately executed at time *t*. The *best spread* is a particular case of the *CRT* when the *best size* is larger than *L*. Cost of the round trip is a multidimensional measure: It combines tightness and depth, as in the case of market quality index and DSS. Obviously, a smaller CRT indicates a more liquid market. In order to choose *L*, we worked out the distribution of trade sizes for all the securities in the sample. It turns out that the most frequently traded quantities for MTS Italy are 2.5, 5 and 10 million of euros. Following Cheung et al. (2005) we evaluate the *CRT* also for *L = 25*. In what follows we will focus on the *CRT* for *L = 10* and we will call it *CRT10*.

Market conditions

We used a couple of indicators to measure market conditions. *Market participants* measures the number of active market makers in each snapshot. It will be considered as an indicator of the degree of competition among the primary dealers. *Absolute price change* is our measure of market's volatility. It is the absolute difference between the average mid prices of two following snapshots. The two measures are frequently used to proxy liquidity. We consider them as indicators of market conditions.

3.3. Trading measures employed in our analysis

The measures introduced so far exploit order book data. Now we turn to measures that rely on trading data. A first common measure is *trading volume*, measured as the quantity traded multiplied by the contract price and then aggregated over the interval between two consecutive snapshots. Other popular measures are the *trading frequency* and the *turnover ratio* that are respectively the number of contracts in a given time interval and the ratio between trading volume and the outstanding, that is the issued quantity of a given security. *Trade size* is simply the average size of trades in the interval between two consecutive snapshots[17].

A widespread liquidity measure, which arises from an econometric estimation, is the *price impact coefficient*. In effect, a liquid market is a market where participants can rapidly execute large-volume transactions with a small impact on prices, and this measure just estimates the price impact of trades. Firstly introduced by Kyle (1985), both Fleming (2003) and D'Souza et al. (2003) underline the importance of its estimation. We estimate the following model:

$$\frac{P_t - P_{t-1}}{P_{t-1}} = \alpha + \beta * NT_t + \varepsilon_t \qquad (1)$$

Where NT is a measure of market activity and more precisely it is either *net trading quantity* or *net trading count*[18]. Even though it necessitates the use of detailed high-frequency data, equation (1) needs to be estimated over a long sample period. We estimated the model both over the whole sample and weekly. We used the regression coefficients as measures of the price impact, and we called them *NTQ* and *NTC* respectively[19].

[17] Trading volume, trading frequency, turnover ratio, trade size match with the measures employed in D'Souza and Gaa (2004) and Fleming (2003), among others.
[18] Net trading quantity and net trading count match with the variables employed in D'Souza and Gaa (2003).
[19] In the following analysis we will also provide an estimation of several models, as in Fleming (2003), for the whole sample.

4. The Microstructure of Italian Government Securities Markets

Italian Government finances its public deficit by issuing debt securities, on December 2006 they account for 80% of the public debt. The Italian Market of Government Securities (GS) consists of two sectors: The primary market[20] and the secondary market. In the primary market bonds and notes are mainly placed through auction mechanisms. The Italian Ministry of Treasury avails itself of a Primary Dealership system. Among Primary Dealers it chooses a group of so called Specialists, which status entails themselves of privileges and obligations: For instance, Specialists have the faculty to participate to reserved auction reopening; they have to provide certain levels of liquidity both to the cash and to the Repo markets to preserve their status. In the secondary markets GS are traded in two ways: Organized exchange markets, and over-the-counter. In the latter the main players are investment banks and most of them participate also to the primary market. In the former we can distinguish a retail market (i.e. the MOT) and a wholesale market. The majority of trading occurs on wholesale markets. In particular, among the wholesale markets, MTS (*Mercato Telematico dei titoli di Stato*) is the leading market in Europe for the trading of fixed income securities with its over 1200 participants throughout Europe and average transaction volumes of up to 85 billion euros a day (single-counted)[21]. Italian bonds, however, are quoted on other trading electronic platforms as well. In Europe electronic trade accounts for 75% of daily trade volume for government bonds[22]. Since the analysis of the primary market is beyond the scope of this paper, this section will focus on the secondary market and in particular on the MTS market.

4.1. MTS model: An overview

MTS was the first electronic market for GS and it was introduced in 1988 by the Italian Treasury as a platform for co-ordinating the activity of its primary dealer group within Italy. The original model required that, in exchange for committing liquidity, banks would be recognised as primary dealers, and they would gain the right to participate in auctions and receive a steady supply of new issues; however, this model was limited to the single issuer within the lira currency zone.

The development of MTS, from the privatisation in 1997 to the establishment of EuroMTS in 1999[23], tracks the development of the European bond markets. Indeed, the introduction of the euro and the progress of electronic trading and settlement motivated MTS to develop a strategy to exploit the new-found scalability of its model across both geography and bond type. Moreover, with the beginning of the single currency zone, the dealer community supported the emergence of specific standards related to issuance sizes and transparency of the issuance policy. Eventually, the MTS platform became the natural catalyst for setting common standards of bond issuance, quotation requirements and transparency of the issuance policy. The first stage was the foundation of EuroMTS, the pan-European benchmark platform, to promote such standards, and the birth of the so called *Liquidity Pact*. According to the Pact, dealers and issuers undertake commitments to each other, and the MTS platform is used by both sides of the market to monitor and bring transparency to it.

The key to the success of this trading platform is to be found not only in its technical capabilities, but also in MTS's ability to bring together issuers and dealers and to induce them to commit to a few simple rules. The aim was to foster secondary market liquidity. In addition, in some countries

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[20] For a deeper analysis of the primary market see Bagella et al. (2006).
[21] Source: MTSGroup web site.
[22] See Pierron (2004), mentioned in Paesani and Piga (2007).
[23] Scalia and Vacca (1999) provide a description of the developments of the Italian Treasury securities secondary market occurred in the last two decades.

the quoting and trading performances on MTS are taken into account by government debt management offices to admit dealers to the primary market. As many other multilateral agreements, the *Liquidity Pact* comes with benefits but also with costs since it may favour free riding: Any participant can profit from the liquidity provided by the other participants and make other dealers to lose money[24].

The last stage of the MTS transformation was the merge of EuroMTS with MTS S.p.a. into MTS Global Market in 2001. Moreover, since the end of the nineties the MTS system expanded to other country markets and to high quality non government bond[25]. The MTS model uses a common trading platform; however, regulatory responsibilities are within the competence of domestic authorities. In effect, rules governing electronic platforms share some common characteristics, but there are some differences across countries. For instance markets makers must have net assets of at least €100 million to join MTS Belgium and just €39 million to join MTS Italy. Shares in EuroMTS are held by MTS S.p.a., whose shareholders are Borsa Italiana S.p.a. and the major financial institutions that have a strong presence in the European secondary government bond markets. Till recently, one of the main shareholders of MTS S.p.a. had been Euronext, the company which controls the Paris stock exchange and other major stock exchanges in Europe. In the occasion of the merge between Euronext and New York Stock Exchange, the shares of MTS S.p.a. owned by Euronext were bought back by Borsa Italiana S.p.a..

4.2 MTS microstructure

Let now consider the structure and functioning of MTS. MTS is a wholesale inter-dealer market, this means that individuals cannot access to it. Although the requirements for participants depend on the market in which they operate, we can broadly distinguish two categories of participants, namely market makers and market takers. The former have to quote continuously two-way firm and immediately executable proposals for a selected subset of securities. The prices usually have to be posted for at least five hours per day and for a certain minimum quantity, and they are subject to maximum spread obligations depending on bonds maturity and liquidity. Each market maker can voluntarily quote other securities as well, facing in this case no constraint on price proposals. No market making obligation applies to market takers that can buy or sell at the given prices. MTS markets are an example of quote-driven electronic order book. This implies that market makers' quotations are aggregated in a book according to price and side of the market. Since orders of round lots[26] are executed according price priority and time priority (i.e. first in first out) and the quoted proposals are firm and immediately executable, we can say that MTS works as a limit order book. To facilitate the handling of large transactions, minimum lot sizes[27] are high and trading rules grant traders a high degree of anonymity[28]. In effect, price proposals are anonymous and the identity of the counterparty of a trade is revealed only after the trade is executed for clearing and settlement

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[24] For instance, in August 2004 Citigroup in few seconds flooded MTS with sales and then it repurchases a large amount of bond at a lower price, earning about 15 million euros at the expense of the other market makers, see Munter and van Duyn (2004).

[25]On March 2007 the markets of the MTS platform are the following: EuroMTS , MTS S.p.a. (MTS Italy), EuroCredit MTS, NewEuroMTS, EuroBenchmark Treasury Bills Market, EuroMTS Linkers Market, MTS Cedulas Market, MTS Quasi-Government Market, EuroGlobalMTS, MTS Amsterdam, MTS Austrian Market, MTS Belgium, MTS Denmark, MTS Deutschland, MTS España, MTS Finland, MTS France, MTS Greek Market, MTS Ireland, MTS Israel, MTS Poland, MTS Portugal, MTS Slovenia, BondVision, EuroMTS Indices.

[26] Odd lots are admitted but they are subject to market makers' acceptance.

[27] Proposals must be formulated for a minimum quantity equal to € 10, € 5 or € 2.5 million depending on the instrument (bucket of maturity, liquid/ benchmark security).

[28]Actually, this was not the case when MTS was founded. Indeed, in July 1997, 10 years after its inception, MTS switched to a new operation regime in which the names of market-makers who post bid and ask quotes for each security are not revealed. See Scalia and Vacca (1999) analyze this change in the degree of transparency.

purposes. In particular if a central counterparty (CCP) is used, counterparties will not know identities; if the trade is settled bilaterally, only the counterparties will know identities. Moreover, market makers are not required to show the maximum quantity they are willing to trade: A participant may limit the display of his proposals to a partial amount (drip quantity) between the minimum trading lot and the total amount of the proposal (block quantity). Both cash and repo transactions are admitted[29]. Even if anonymity in transactions is guaranteed, the MTS system is highly transparent since quotes and transactions go directly to data vendors as Bloomberg and Reuters. As a result, they are immediately available, at a cost, to any market participants. Moreover, data[30] provide the information about the first five levels of the order book.

Pre- and post-trade[31] information is available outside the electronic platform space in real-time. Dealers on the MTS platform have access to real-time executable quotes and to a fully transparent order book. Professional investors have an indirect access to the same information through data vendors. In particular, the MTS group aggregate information through the so called MTS Data. MTS's data products are grouped into two areas, namely MTS Live Market Data and MTS Value-Added Data. MTS Live Market Data[32] includes *real time* bond market data providing best bid and offer quotes, market depth, as well as the last traded price, all complete with related volumes. It is important to underline that these prices are actual traded prices or prices that are live and executable on the MTS platform. Data are available to data vendors[33] also at snapshot[34], delayed and end-of - day frequencies. MTS Value-Added Data Products are made up of MTS Daily Data, MTS Historical Data, EuroMTS Indices and MTS Today, which is a daily analytics report. In particular, MTS Daily Data includes the reference prices[35] and corresponding yields calculated for all European government, Treasury bills and non-government bonds traded on MTS Markets at 11:00 CET as an "Open" fixing and at 16:00 CET as a "Close" fixing. It is worth to note that these prices are published immediately after each fixing. With respect to data available to anybody at no cost, the daily price statistics of MTS Markets for cash and repo segments can be accessed and downloaded by selecting the corresponding MTS market on the MTS Group's website. These lists are updated daily at the close of the market and display the date of trading, the ISIN code, the type of bond, the description of each security and the minimum and maximum price of trades executed along with the average daily weighted price for each security.
As already mentioned, MTS markets are active in several European countries, an exception is the London-based EuroMTS, designed for trading in European benchmark issues between the largest and most active dealers. An interesting feature of this system is that benchmark government bonds tend to be traded both on EuroMTS and on domestic (MTS) systems. In the period 2004-2006 only 5% of the Italian bonds and notes exchanged on electronic systems have been traded on EuroMTS and about 95% on MTS Italy[36]. CGFS (2001) analyses the daily trading volumes and bid-ask spreads of benchmark Italian government bonds (BTPs) quoted on MTS Italy and shows that no

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[29] For additional details see "MTS Regulations - Governing the Wholesale Italian and Foreign Government Bond Market" available at http://www.mtsspa.it/content/about/download/mtsmarketrules.pdf.
[30] Both cash and repo data are displayed.
[31] For an assessment of pre- and post-trade information, from the perspective of the transparency provisions envisioned in 2004/39/EC Directive disciplining the functioning of markets for financial instruments in Europe (MiFID), see Paesani and Piga (2007).
[32] MTS Market Data is managed by EuroMTS on behalf of the group of MTS Companies.
[33] The complete list of data vendors includes: Bloomberg LP, Interactive Data Comstock, E-class/Class Editori, Ecowin, Fininfo, FTID, Il Sole 24 Ore, Infotec, Kestrel Inc., Moneyline Telerate, Reuters, Russell Mellon, SIA Cedborsa, Telekurs Financial, Thomson Financial, Traderforce, Valuelink Information.
[34] For instance Traderforce's clients are allowed to download all the data available at a certain point in time as if they "take a picture" of the market in that moment.
[35] The algorithm to generate a final Reference Price for each product utilizes both traded prices and quoted best prices, and weights the two.
[36] Source: our elaboration on Monte Titoli Spa.

substantial change in liquidity conditions occurred in this market in the first five months of activity of the new pan-European network, i.e. from April to August 1999. This suggests that the latter has mainly captured transactions that were previously carried out over the counter. Cheung et al. (2005) notice that in general large numbers of market makers are active on both trading platforms, suggesting that there are not any competitive advantages in terms of quoting rights. Furthermore, they show that, although domestic MTS markets usually offer better spreads, the difference with the EuroMTS is small.

One important feature of MTS Italy is in the different set of market makers' obligations. In effect, the Italian Treasury, as mentioned above, defines a set of obligations and privileges for Specialists. Since the majority of market makers are also Specialists, this regulation affects the markets. In particular, the Treasury requirements are usually stricter with respect to the MTS ones, and, as a consequence, most of the market participants are committed to the Treasury's obligations. Table 4.1 summarizes the differences between the set of rules imposed by MTS Italy and those imposed by the Ministry of Economy and Finance (MEF), to which are subject the securities in our sample[37]. The two regulations pursue liquidity in quite different ways. MEF rules apply to all the securities available on the market and, as a consequence, also to all the off-the-run issues. On the other end, the Management Company (i.e. MTS) periodically assigns to Primary Dealers buckets of securities that are "suitably differentiated in terms of liquidity, maturity date and other financial characteristics, for a minimum number laid down in the Rules, taking account of the need to ensure real competition between the Primary Dealers" (Art. 17, MTS Regulations, Governing the wholesale Italian and foreign government bond market, 2005). The main distinction is between the "liquid" bucket and the "not liquid". For the period under examination, i.e. 2004-2006, a security is said to belong to the "liquid" bucket if it is listed on EuroMTS. It turns out that all the bonds in our sample would be assigned to the "liquid" bucket, which is also the one that is subject to the most severe commitments[38]. In effect, MTS defines precisely for each bucket bounds of maximum spread and minimum quoted quantity. The approach of the Italian Treasury is totally different. The Treasury monitors Specialists awarding points which are proportional to how the Specialist makes the market with respect to the other participants. For instance, points are assigned according to a measure of spread that is standardized with respect to the market of all the traded securities[39]. The Bank of Italy participates as well in the Treasury monitoring activity through the computation of the Efficiency Index. This index keeps into account the number of quoted and traded securities, and quoted bid-ask spread and quantities weighted for the exposition time on the order book. The obtained scores allow MEF to rank Specialists: ranking is one of the criteria used by Italian Treasury in order to select Specialists for highly remunerative services such as private placements[40].

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[37] The securities included in our samples are listed in section 4.
[38] This is not the case for CTZs for which there is no bucket distinction.
[39] The index is calculated as the simple average of the standardized bid – ask spreads for all the bonds quoted daily for at least 6 hours. For a generic primary dealer (PD) *X*, the standardized spread for bond *i* quoted for at least 6 hours is equal to:

$$z_i^X = \frac{s_i^X - \overline{s_i}}{\sigma_{s_i}}$$

Where s_i^X is the daily average spread of the bond *i*, quoted for more than 6 hours by the PD *X*, calculated by weighting each bid-ask spread by the exposition time. $\overline{s_i}$ and σ_{s_i} are, respectively, the average and standard deviation of the spreads of bond i, calculated as indicated before, for all the Primary Dealers.
[40] All the information related to Specialists (i.e. list, ranking and evaluation criteria) are available online at http://www.dt.tesoro.it/Aree-Docum/Debito-Pub/Titoli-di-/Aste-Titol/

Table 4.1 MTS and Treasury rules applying to the securities comprised in our sample

<table>
<tr><th></th><th colspan="2">Compliance time</th><th colspan="2">Bid-Ask Spread</th><th colspan="2">Volume</th><th colspan="2">Other</th></tr>
<tr><th></th><th>MTS</th><th>MEF</th><th>MTS</th><th>MEF</th><th>MTS</th><th>MEF</th><th>MTS</th><th>MEF</th></tr>
<tr><td>securities</td><td>all assigned bond</td><td>all</td><td>"liquid" bucket
max spread</td><td>all</td><td>"liquid" bucket
min quote size (mln)</td><td>all</td><td>–</td><td>all</td></tr>
<tr><td>BTP30</td><td rowspan="6">Two-way proposals displayed for at least 5 hours per day</td><td rowspan="6">Points proport. to the number of GS quoted for at least 6 hours</td><td>0.2</td><td rowspan="6">Points proport. to a standardized spread#</td><td>2.5</td><td rowspan="6">Points proport. to (%Specialist 's traded volume - average % of the non-Specialist)</td><td rowspan="6">–</td><td rowspan="6">Bank of Italy "Efficiency Index"* and distributional capacity based on HRF**</td></tr>
<tr><td>BTP10</td><td>0.07</td><td>5</td></tr>
<tr><td>BTP 5</td><td>0.05</td><td>5</td></tr>
<tr><td>BTP 3</td><td>0.04</td><td>5</td></tr>
<tr><td>CTZ</td><td>0.04+</td><td>2.5</td></tr>
<tr><td>BTP 10 ind</td><td>–</td><td>2.5</td></tr>
</table>

Note: The rules apply to the time span and the securities in the present research. Sources of the information are respectively www.mtsspa.it and “MTS Regulations - Governing the Wholesale Italian and Foreign Government Bond Market” for MTS and the Annex to the Public Director Decree N.140483 of December the 29th 2005 for the Italian Treasury. # the formula is displayed in footnote 39. + the same bound applies to “not liquid” bucket. The “liquid” bucket includes on-the-run and first off-the-run securities. * the index keeps into account the number of quoted and traded securities, and quoted bid-ask spread and quantities weighted for the exposition time. **since 2006, the parameter is evaluated quarterly on the basis of *Harmonized Reporting Format*.

5. Data

Our dataset covers transactions and proposals of the Italian medium and long term government bonds being traded on the MTS platforms from January 2004 to December 2006. For each day in the sample we have the on-the-run and the corresponding off-the-run security for each segment. The series of each security ends six months after it becomes the second off-the-run. Table 5.1 reports the exact time span for each security in the dataset. We mainly focus on medium and long term fixed coupon bonds (BTPs), which on December 2006 accounted for 59.93% of the outstanding securities. We also consider two year zero coupon bonds, CTZs, and the ten year index linked BTPs.

Table 05.1 - Data

Security	Isin code	on/off the run	From	Coupon rate	Maturity	Starting data	End sample	Numb. quotes	Numb. contracts
BTP30	325682	off	17-Sep-03	5.75%	1-Feb-33	1-Jan-05	30-Nov-05	1,432,618	9,210
	353515	on off	17-Sep-03 12-Oct-05	5%	1-Aug-34	1-Jan-05	31-Dec-06		
	393465	on	12-Oct-05	4%	1-Feb-37	12-Oct-05	31-Dec-06		
BTP10	347233	off	29-Jan-04	4.25%	1-Aug-13	1-Jan-04	13-Nov-06	1,311,264	59,491
	361838	on off	29-Jan-04 30-Aug-04	4.25%	1-Aug-14	27-Jan-04	13-Nov-06		
	371991	on off	30-Aug-04 28-Apr-05	4.25%	1-Feb-15	27-Aug-04	13-Nov-06		
	384453	on off	28-Apr-05 27-Feb-06	3.75%	1-Aug-15	27-Apr-05	13-Nov-06		
	401958	on	27-Feb-06	3.75%	1-Aug-16	23-Feb-06	13-Nov-06		
BTP 5	353209	on off	15-Sep-03 13-Apr-04	3.50%	15-Sep-08	1-Jan-05	28-Feb-05	830,961	23,577
	365207	on off	13-Apr-04 13-Jan-05	3%	15-Apr-09	13-Apr-05	31-Jul-05		
	379959	on off	13-Jan-05 15-Jun-05	3%	15-Jan-10	11-Jan-05	13-Mar-06		
	387292	on off	15-Jun-05 13-Mar-06	2.75%	15-Jun-10	13-Jun-05	17-Nov-06		
	402629	on off	13-Mar-06 14-Sep-06	3.50%	15-Mar-11	13-Mar-06	17-Nov-06		
	411281	on	14-Sep-06	3.75%	15-Sep-11	12-Sep-06	17-Nov-06		
BTP 3	361115	on off	14-Jan-04 28-May-04	2.75%	15-Jan-07	14-Jan-05	28-Feb-05	783,354	32,115
	367423	on off	28-May-04 28-Jan-05	3%	1-Jun-07	28-May-05	31-Jul-05		
	380485	on off	28-Jan-05 28-Jun-05	2.75%	1-Feb-08	28-Jan-05	28-Feb-06		
	387770	on off	28-Jun-05 30-Jan-06	2.50%	15-Jun-08	28-Jun-05	31-Jul-06		
	400812	on off	30-Jan-06 28-Jun-06	3%	1-Feb-09	30-Jan-06	31-Dec-06		
	408524	on	28-Jun-06	4%	15-Jun-09	28-Jun-06	31-Dec-06		
CTZ 24 m	364676	on off	29-Mar-04 27-Jul-04		28-Apr-06	24-Mar-04	28-Apr-06	2,933,702	44,387
	369706	on off	27-Jul-04 24-Mar-05		31-Jul-06	23-Jul-04	25-Jul-06		
	383119	on off	24-Mar-05 27-Sep-05		30-Apr-07	22-Apr-05	1-Dec-06		
	392699	on off	27-Sep-05 24-Apr-06		28-Sep-07	23-Sep-05	29-Dec-06		
	405105	on	24-Apr-06		30-May-08	21-Apr-06	29-Dec-06		
BTP 10 ind	362590	on off	18-Feb-04 23-Jun-06		15-Sep-14	3-Jan-05	29-Dec-06	1,079,962	3,843
	408521	on	23-Jun-06		15-Sep-17	22-Jun-06	29-Dec-06		
total								8,371,861	172,623

Data are provided by the Italian Ministry of Treasury that collects them directly from the MTS Italy market. *Ad hoc* software allows downloading the data at the desired frequency. This data source is somehow unique since it shows all the quotes and the relative quantities that are active on the market. The implication is that we are allowed to see the complete book (all the quotes and block quantities. Unfortunately drip quantities are not available to us at present) whereas traders can only access a part of this information. Indeed, while market participants can see just the five best bid and ask quotes and the drip quantities insisting on them, our dataset includes *all* the non-repeated quotes and for each quote we know the whole (block) quantity. This will permit us to provide particularly accurate measures of the depth of the market. The point will be clearer as soon as we are introducing the employed liquidity measures. As we will show in the next sections, when we have more than five bid (ask) prices in the order book, the prices beyond the fifth are usually so low (high) to be irrelevant[41]. The minimum increment in quoted prices, i.e. the tick size, is one hundredth of the price for all the securities in the sample but CTZs, whose tick size is one thousandth of the price. Each line of the database is a "snapshot" of the information related to a certain security at a precise point in time. The dataset contains all the snapshots between 8:30am and 5.30pm at a five-minute frequency[42]. All the contracts are also available and they include the price and the sign of the trade and the trade time. Information about the number of market participants and the number of times a quote (either price or quantity) has been updated in the previous five minutes is also available. We end up with 8,371,861 proposals and 172,623 contracts.

The raw dataset contains some errors due to missing records and outliers. We filtered data prior to performing our analysis; the filtering methodology is described in Appendix A. Transactions and quotes are available for both on-the-run and first off-the-run securities, where for on-the-run we mean the most recently auctioned security. The availability of both on and off-the-run will permit us to understand when, in terms of liquidity, an on-the-run security becomes the reference for its maturity segment, i.e. when it becomes a *benchmark.*

6. Empirical Results

In the previous sections we presented a number of conventional and new measures in order to assess the market liquidity. In this section we display the results of the empirical analysis. We start with univariate statistics focusing on the 10 year BTPs both on-the run and off-the-run. The data are at 5-minute frequency in the case of the order book measures, and at daily frequency in the case of trade measures. Furthermore, we compute the price impact coefficient both on the whole sample and at weekly frequency. We then present the correlation coefficients among those measures in order to show the mutual relationships among different measures, their reciprocal consistency, their reaction to market conditions. We present correlation coefficients computed on data both at 5-minute frequency and at weekly frequency[43]. The analysis of summary statistics and correlation coefficients allows us to select a list of indicators that give a comprehensive description of the most important features of order book and trading data. Finally, we compare the liquidity measures across all the securities in the sample in order to identify the most liquid securities. Furthermore, for each liquidity measure we present the correlation between its values calculated on couples of different secutirities. This analysis allows us to evaluate commonality in liquidity. In order to

[41] This is not true in the case of CTZs, as we specify below.

[42] We ran a preliminary analysis on samples selected at both 30 seconds and 10 minutes frequency. The 30 seconds frequency data did not show a significant amount of additional information.

[43] Univariate statistics and correlations computed on the other securities included in the sample are available on request. Comparisons of univariate statistics across the securities included in the sample will be presented in section 6.4.1.

compare different securities, where it was necessary we transformed prices in yields. In the latter case, data are only at weekly frequency.

When possible, we compare the values of the liquidity measures we found on MTS with the values of the same measures on other platforms for analogous government securities. Our yardsticks were one of the major Interdealer Broker electronic platforms in the U.S., BrokerTec[44], and the Canadian Interdealer Brokered market for Government bonds[45]. On those markets we considered the on-the-run 10 year maturity bond. The typical 10 year government bond in U.S., Canada and Italy have different outstanding. The total issued amounts are US$ 22-28 mln, CA$ 10 mln, € 20-25 mln, respectively, in the period 2004-2007. Taking this major difference into account, we claim that the comparison among the same liquidity measures is still informative.

6.1. Summary statistics

In this section we present the summary statistics of the liquidity measures for the 10 year BTPs[46]. Table 6.1 refers to the order book measures at a 5-minute frequency. Table 6.2 and 6.3 refer to trade measures at daily frequency, except for trade size, which is calculated on all the contracts in the sample. The tables can be found at the end of the present section and are split in two panels, A and B: The former is computed on on-the-run securities, the latter on off-the-run securities.

Tightness

The average value of the best spread amounts to 0.025 per cent of par. The dispersion around the average is small: The standard deviation amounts to 0.01; the third quartile is just 0.005 larger than the average value. The average value of both spread and weighted spread are, by definition, larger than the best spread. However their dispersion around the average value is even narrower than best spread's dispersion[47]. The average best spread on MTS turns out to be larger than the best spread on the on-the-run 10-year maturity U.S. Treasury note[48], which amounts to 1.5 per cent of par. However, it is greatly smaller than the best spread on the on-the-run 10-year Government of Canada bond, which amounts to 0.076 per cent of par[49].

Figures 6.1-6.4 are worked out averaging each 5-minute interval over the whole sample. The *best spread* shows a sort of U-shaped pattern. The highest value is achieved at the beginning of the day and it is around 4 ticks, then after 9.00 it falls at 2 ticks and it gradually rises again after 15.00. This is consistent with the empirical findings of Huang et al. (2002) for the USA Treasury Interdealer Broker market (IDB). The peak around 14.30 coincides with the opening of US financial markets. While the peak is common to all the measures of spread, the U shape is not so clear in the case of spread, and weighted spread is only slightly hump-shaped.

Depth

The quantity available for trade in the whole order book amounts, on average, to € 157 mln. However, only 24 per cent of it, € 37 mln, is available at the best quotes. Another 48 per cent of it is

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[44] Data were drawn from Fleming and Mizrach (2007).
[45] See See D'Sousa, Gaa, Yang (2003).
[46] We will include foot notes when the evidence on the other securities in the sample is not consistent with the one on 10 year BTPs.
[47] Best spread is even tighter, 0.023, and less dispersed in the hours of trade concentration, i.e. between 9:00 a.m. and 2:00 p.m.. However, spread and weighted spreads are marginally larger in the hours of trade concentration. Data on the other securities in the sample confirm the same evidence, particularly in the case of simple spread. We will come back on the rationale of the wider spread in hours of trade concentration.
[48] See Fleming and Mizrach (2007)..
[49] See D'Sousa, Gaa, Yang (2003).

available at the second best quote. The average best size on MTS turns out to be smaller than the best size on the on-the-run 10-year maturity U.S. Treasury note[50], which amounts to \$ 48 mln. However, it is much larger than the best size on the on-the-run 10-year Government of Canada bond, which amounts to \$ 2.4 mln[51].

The dispersion of quote size around its average value is large, particularly in the case of best size. The coefficient of variation amounts to 0.40 in the case of total quote size and to 0.62 in the case of best size[52]. All the other measures of quote size show a large coefficient of variation but the quote size per participant. Data show that each market maker is available to trade € 8 mln on average and the dispersion around that average value is very small[53]. This means that the high variability of quote size depends on the number of dealers who participate to the market. In effect, the number of market participants amounts, on average, to 19 and shows a coefficient of variation which is very close to the coefficient of variation of total quote size[54], namely 0.39.

As in the case of tightness measures, depth measures show a hump-shaped pattern with lower values at the beginning and at the end of the day. The *weighted depth*, that takes into account the position of the quoted sizes in the book, follows the pattern of the other depth measures but at the same time underlining the changes in liquidity during the day. The fall in liquidity at 2:30 p.m. is evident in this case as well. Indeed, it turns out that at that time some market participants leave the market. Conversely, the participants that do not exit reduce the quoted size and widen the spreads. The reduction of the quote size per market participant is consistent with Kavajecz (1999), who finds that traders reduce depth around information events to reduce their exposure to adverse selection costs. In our case, the information event that daily hits the market is the opening of New York financial markets. This phenomenon disappears in the following 5-10 minutes.

Breadth
The average distance between best and worst quote, the steepness, amounts to 3 per cent of the mid price. The median value of steepness, however, is smaller, 2 per cent. Interestingly the steepness, which is sometimes regarded as a measure of liquidity[55], seems to behave not consistently with the other measures of liquidity. Indeed, Figure 6.3 shows that during the hours of trade concentration, when the spread variables and the size variables indicate higher liquidity, we find higher values of the steepness and therefore apparently lower liquidity, according to one of the interpretations of this measure. We will elaborate on steepness and its relationship with liquidity measures later on. For the time being, suffice to say that, as long as we correct the *steepness* to keep into account the underlying quantities, as in the *slope*, we obtain a measure whose conceptual relationship with liquidity is clearer. The slope computes how far from best price a dealer has to depart, if he wants to

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[50] See Fleming and Mizrach (2007).
[51] See D'Sousa, Gaa, Yang (2003).
[52] In hours of trade concentration quote size is even larger than on average. However, the increase in size during the hours of trade concentration is not uniformly distributed on all the order book. The comparison of hours of trade concentration and the rest of the day shows that total quote size jumps from € 113 mln to € 190 mln. On the contrary, best size increases only from € 31 mln to € 42 mln. Furthermore, while in the hours of trade concentration the dispersion of total quote size significantly falls, the coefficient of variation of best size keeps on being larger that 0.5. Other securities in the sample generally confirm previous evidence on quote size. However, in the case of BTP3 and BTP5, the increase of quote size in the hours of trade concentration is smaller.
[53] Even during the hours of trade concentration the quote size per participant is not larger than it is on average. On the contrary is slightly smaller.
[54] Most of the variability in the number of participants to market depends on the fall in market participation in morning and afternoon hours. In the hours of trade concentration, on average the market is made by 23 dealers. On the contrary, in the rest of the day, the number of market participants falls to 14. See Figure 5.4 for the graph of daily evolution of the number of participants. Furthermore, the dispersion in the number of market participants around those average values is small in the hours of trade concentration and large in the rest of the day.
[55] See for instance Dunne et al. (2006).

trade € 100 mln. Therefore, the smaller the slope, the more liquid the market is. Accordingly, Figure 6.3 shows that the slope falls in the hours of trade concentration. *DS* and *DSS* exhibit a pattern that is very close to the slope's one.

Trading measures

Do the order book features fit with the trading needs revealed by market? In order to answer this question, trading data have to be examined. Table 6.2 shows that the average trade size amounts to € 6.5 mln and the corresponding coefficient of variation is equal to 0.37. Furthermore, Table 6.3 shows that, for most of the securities in the sample, the frequency of trades whose size is larger that €10 mln is smaller than 2 per cent. The comparison of trade size data with best size data shows that the quantity available on the book at the best price seems to be adequate to the revealed trade needs of the market. On average, at the best price, an amount of € 37.2 mln is available for trade, and best size is larger than € 20 mln in 75 per cent of cases. Even though more careful analysis of execution quality could be carried out, a tentative supposition could be put forward: Most of trading could occur at the best price. A further confirmation of the possible good execution quality comes from the Cost of the round trip for an amount of € 10 mln: CRT and best spread show very similar values of the descriptive statistics. This means that buying and selling a quantity larger than the size of most of the recorded trades has a cost that is equal to the best spread[56]. Despite previous evidence points to a supply of liquidity consistent with market needs, an alternative interpretation could be elaborated. Trade size could be affected by best size and the causality could be inverse: Most of the trading concentrates around € 6.5 mln because larger amounts are discouraged to appear on MTS, given the limited best size available. For the time being we are not able to give a final answer to the issue. We leave it to further investigation, probably based on additional data.

Daily trading volume is not very large and, furthermore, it is exceedingly variable. The average daily volume amounts to € 310 mln. The corresponding coefficient of variation is equal to 0.57. Half of the days in the sample show a trade volume in the interval € 188 – 403 mln. Daily trading frequency is equal to 48, on average, and average turnover is 2.9 per cent. On the BrokerTec platform, daily trading volume of the on-the-run 10-year maturity U.S. Treasury note is $ 27,143 mln, more than 60 times the trading volume on the MTS platform. The corresponding daily trading frequency is 10,335. On the Canadian IDB market, daily trading volume of the on-the-run 10-year maturity Government of Canada bond amounts to $ 193 mln, and daily trade frequency is equal to 55. In conclusion, the trading activity on MTS is much smaller that the trading activity on one of the corresponding IDB electronic platform in U.S.. Nevertheless, the liquidity supplied by the order book on MTS seems to be relevant, and adequate for the market needs, even though smaller than the liquidity on the U.S. IBD market.

Until now only data on on-the-run securities have been presented. Do off-the-run securities show the same features as the on-the-run ones? Before answering the question, let us quickly mention two other indicators included in Table 6.1. Market quality index is a synthetic, multidimensional indicator of liquidity which will be used in the following in order to compare the liquidity of bonds with different maturity. Its variability around the average value is smaller than the variability of other liquidity measures. Finally, absolute price change measures price variability and will be used in the following as an indicator of market conditions. Figure 6.4 shows *absolute price change* is lower in the first half of the day and it switches to a higher level after 2:00 p.m..

On-the-run and off-the-run securities

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[56] The Cost of the round trip for an amount of € 25 mln shows a mean only slightly larger than the mean of CRT10 and even a smaller standard deviation.

As expected, trading measures show a sharp difference between on-the-run and off-the-run securities[57]. In particular *trading volume*, *trading frequency* and the *turnover ratio* for the on-the-run securities, Table 6.2 panel A, are on average twice as big as the off-the-run ones[58], Table 6.2 panel B. Furthermore, in the case of off-the-run securities trading volume and trading frequency are not only smaller, but they are also more volatile. The coefficients of variation of both trading volume and trading frequency are 0.57 on the on-the-run bonds and 0.80 on the off-the-run bonds. The unique trading measure which shows similar values in the case of on-the-run and off-the-run securities is trade size. Trade size is, on average, about 6-7 millions of euros for 10 year BTPs, and it is slightly larger on the off-the-run securities. These results indicate that trading variables could be helpful in the evaluation of when an on-the-run security becomes the benchmark reference for its maturity segment.

Given the higher trading activity recorded in the case of the on-the-run securities, a more liquid order book could be expected for those securities[59]. Surprisingly, all the order book measures do not show any significant difference between on-the-run, Table 6.1 panel A, and off-the-run securities, Table 6.1 panel B. Spread measures have the same average values. Size measures are often even better in the case of off-the-run bonds than in the case of on-the-run bonds[60]. The striking difference in the performance of trading measures and order book measures is surprising. Spreads and quote size may reflect three different costs faced by market makers: Asymmetric information costs, inventory costs and order processing costs[61]. Asymmetric information costs are related to the lack of knowledge on the true value of the securities by the market makers. In order to prevent the lack of information to generate systematic losses, market makers extract information on the true value from the order flows[62]. As a consequence, the ask price quoted by the market maker, which reflect the expected value conditional on a buy order, is always higher than the bid price, which reflects the expected value conditional on a sell order. Inventory costs come from the risks associated to the financial portfolio held by the market makers. When a proposal posted by the market maker is hit, his portfolio diverges from the preferred one. Ask and bid prices are set in order to make the portfolio to reverse toward its preferred position. Finally, order processing costs are connected with the market makers operating costs. Now, the asymmetric information and the inventory costs should affect both on-the-run and off-the-run securities; however, the higher trading activity on the on-the-run securities should imply smaller order processing costs for those securities. That is why tighter spreads, larger quote sizes and a larger number of market makers could have been expected on the on-the-run securities.

A reasonable explanation of this evidence has to be looked for in the obligations imposed on market makers on the MTS platform. As already mentioned, in the MTS system market makers subscribe a liquidity pact and they commit to permanently quote a basket of securities for a minimum number of hours a day and within a maximum spread. These obligations are independent on the on-the-run or off-the-run status of the securities[63]. Furthermore, Specialists are monitored by the Italian

[57] As specified above, for each securities our data comprise both the on-the-run and the first off-the-run periods, and the first six months of the second off-the-run period.

[58] This holds across all the securities in the sample but the index linked BTPs.

[59] Fleming (2003) gives evidence of tighter spreads on on-the-run U.S. Treasury notes.

[60] Data on the other securities in the sample mostly confirm the same evidence. Same evidence is conveyed by data on the hours of trade concentration and on the rest of the day. Only in the case of BTP30 almost all the liquidity indicators are better in the case of on-the-run security.

[61] See Alonso et al. (2004).

[62] A buy order is considered as a signal of a true value higher than the market value; the reverse is true in the case of a sell order. That is why market makers quote the security on the basis of its expected value conditional on the sign and the amount of the order flow.

[63] This is true because all the securities under examination are included in the “liquid” bucket. In effect, the obligations are different for securities belonging to the ”not liquid” bucket.

Treasury and they compete both on the on-the-run and the off-the-run segments of the market in order to reach a good ranking. In effect, Tables 5.1 shows that the number of dealers on the markets is, on average, the same on the on-the-run and on the off-the-run securities. Apparently, MTS and Italian Treasury do not take into account that market makers bear higher costs in the off-the-run segment than in the on-the-run one. As a consequence, the number of market makers in the off-the-run segment is higher than it would have been in the absence of obligations and monitoring, and this keeps down off-the-run spreads. Dealers probably compensate smaller profits on the off-the-run segment with higher profits on the on-the-run one, that is, in the event of no obligations and monitoring on the off-the-run securities the spreads on the on-the-run segment would probably be smaller than they are at present. Conversely, the spreads on the off-the-run segment would probably be larger than they are at present.

Table 06.1 – Summary Statistics of Order Book Measures

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
best spread	0.025	0.010	0.020	0.020	0.030	0	0.280
spread	0.049	0.008	0.045	0.050	0.055	0.010	0.280
weighted spread	0.046	0.007	0.043	0.045	0.048	0.010	0.283
best size	37.24	22.97	20	32.5	50	2.5	170
second size	75.77	35.10	50	77.5	102.5	3.75	215
worst size	47.02	31.18	22.5	45	70	0	195
quote size	157.09	62.66	112.5	175	205	5	310
average quote size	45.34	16.94	33.8	48	57	3.75	137.5
weighted depth	88.74	35.51	64.38	93.96	113.75	5	212.5
qte size per partic.	8.18	1.09	7.63	8.07	8.61	1	37.5
steepness	0.03	0.01	0.02	0.02	0.03	0.01	0.06
slope	0.03	0.03	0.02	0.02	0.03	0.01	0.5
DS	3.37	3.25	1.71	2.22	3.44	0.67	42.46
DSS	0.0004	0.0006	0.0002	0.0003	0.0004	0.0001	0.023
mkt quality index	9.43	3.79	6.81	9.52	11.98	0.19	33.51
CRT 10	0.02	0.01	0.02	0.02	0.03	0.00	0.29
abs price change	0.015	0.016	0.005	0.01	0.02	0	0.318
mkt participants	19.31	7.63	14	22	25	1	32
Panel B: off-the-run							
best spread	0.025	0.010	0.020	0.020	0.030	0	0.280
spread	0.049	0.008	0.045	0.050	0.050	0.000	0.290
weighted spread	0.045	0.007	0.042	0.044	0.047	0.000	0.290
best size	39.15	24.32	20	32.5	53	5.0	198
second size	81.16	36.55	55	85.0	107.5	5.00	245
worst size	41.44	28.65	17.5	38	60	0	203
quote size	158.56	62.85	115.0	180	205	5	325
average quote size	46.51	16.79	35.4	49	58	5.00	135.0
weighted depth	91.53	36.34	66.67	97.08	116.67	5	229.6
qte size per partic.	8.28	1.05	7.76	8.25	8.75	2	90.0
steepness	0.02	0.01	0.02	0.02	0.03	0.01	0.06
slope	0.03	0.03	0.02	0.02	0.03	0.01	0.4
DS	3.17	3.19	1.62	2.07	3.14	0.41	31.58
DSS	0.0004	0.0005	0.0002	0.0003	0.0004	0.0000	0.020
mkt quality index	9.92	3.74	7.47	10.15	12.39	0.18	33.18
CRT 10	0.02	0.01	0.02	0.02	0.03	0.00	0.28
abs price change	0.014	0.015	0.005	0.01	0.02	0	0.318
mkt participants	19.33	7.69	14	22	25	1	31

Note: The table report summary statistics for the 10 year BTPs' database at a 5-minute frequency. Panel A refers to on-the-run and Panel B to off-the-run issues. "p" is the p-th percentile of the distribution.

Table 6.2 – Summary Statistics for Trading Measures

	mean	sd	p25	p50	p75	min	max
Panel A: on-the-run							
trading volume	310.01	177.63	185.72	275.32	403.05	9.94	1054.51
trading frequency	47.59	26.97	28	42	63	1	156
turnover	2.85	2.45	1.31	2.13	3.51	0.08	19.62
tradesize	6.48	2.41	5	5	10	0.5	45
Panel B: off-the-run							
trading volume	176.51	142.20	83.35	144.57	230.95	4.92	1739.55
trading frequency	24.88	19.72	12	21	33	1	231
turnover	0.82	0.67	0.38	0.66	1.07	0.02	7.10
tradesize	6.90	2.51	5	5	10	1	35

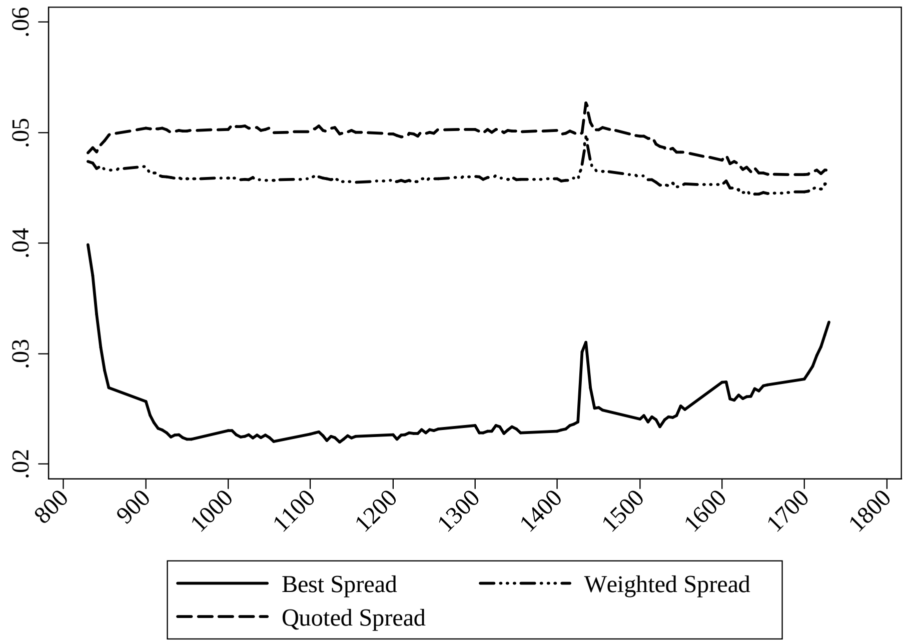
Note: The table report summary statistics for the 10 year BTPs' database. Trading volume, trading frequency and turnover are computed at a daily frequency; trade size is computed without time aggregation, i.e. on all the contracts in the sample. Panel A refers to on-the-run and Panel B to off-the-run issues. "p" is the p-th percentile of the distribution. Trading volume is expressed in millions of euros, turnover is expressed as a percentage, trading frequency and trade size are pure numbers.

Table 6.3 – Summary Statistics for Trade Size

	tradesize	mean	sd	Perc.	Cum.
	2.5			60.47	60.47
	5			38.62	99.09
BTP 30	10	3.54	1.50	0.48	99.57
	25			0.04	99.61
	other			0.39	100
	2.5			0.35	0.35
	5			66.61	66.96
BTP 10	10	6.67	2.47	32.68	99.64
	25			0.03	99.67
	other			0.33	100
	2.5			12.29	12.29
	5			59.74	72.03
BTP 5	10	6.10	2.63	27.17	99.2
	25			0.04	99.24
	other			0.76	100
	2.5			3.28	3.28
	5			59.67	62.95
BTP 3	10	6.90	3.11	35.74	98.69
	25			0.22	98.91
	other			1.09	100
	2.5			71.37	71.37
	5			14.11	85.48
CTZ	10	4.03	3.39	11.33	96.81
	25			0.16	96.97
	other			3.03	100
	2.5			33.05	33.05
	5			29.66	62.71
BTP 10 ind	10	6.00	3.26	35.47	98.18
	25			0.05	98.23
	other			1.77	100

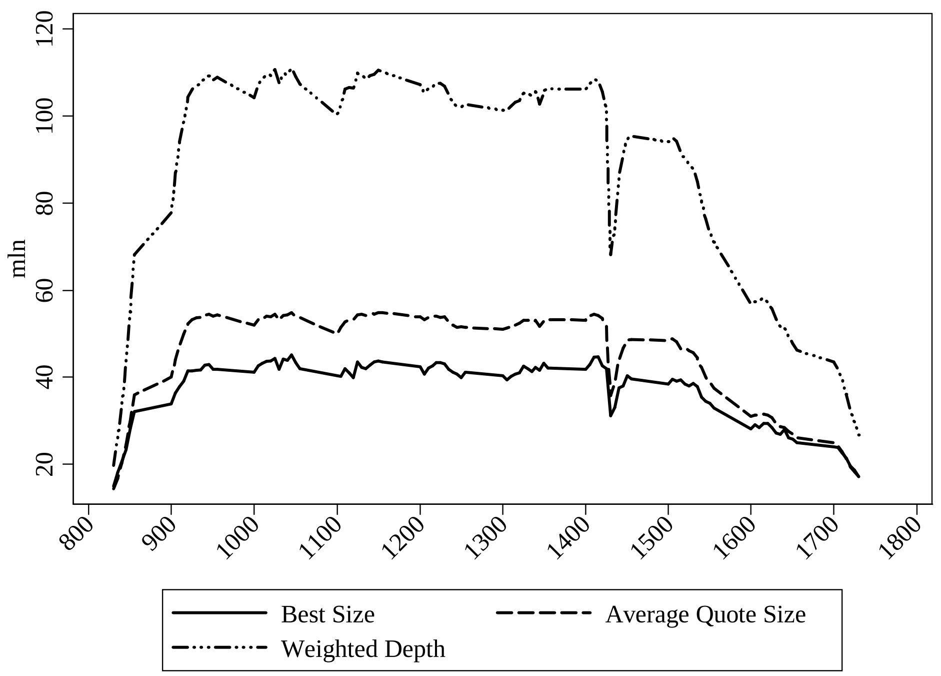
Note: The table reports trade size (in mln of euros) statistics for all the securities and all the contracts in the sample.

Figure 6.1 – Spread Measures



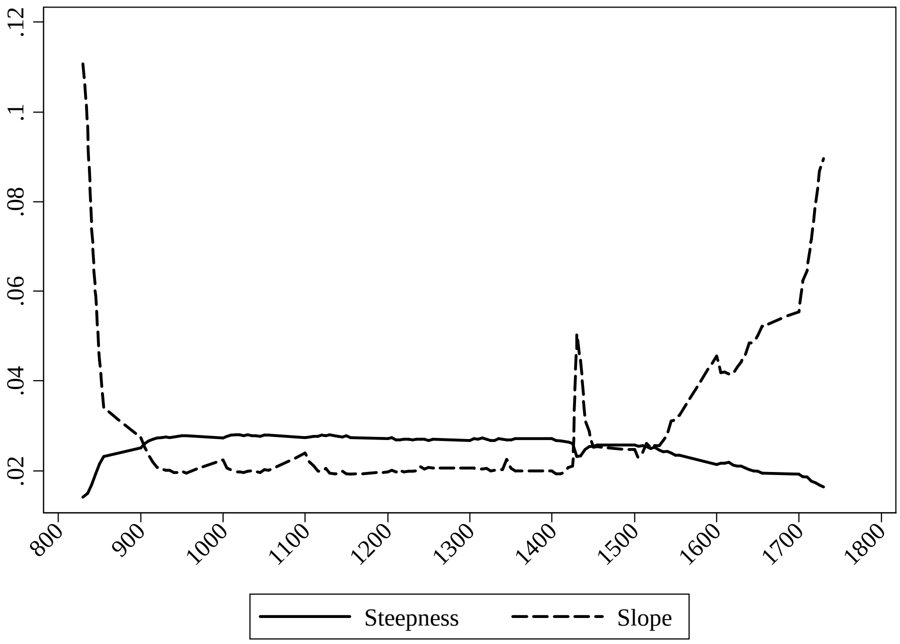
Note: Five minute data are averaged over the whole sample of the on-the-run 10 year BTPs. The spreads are measured in ticks.

Figure 6.2 – Size Measures



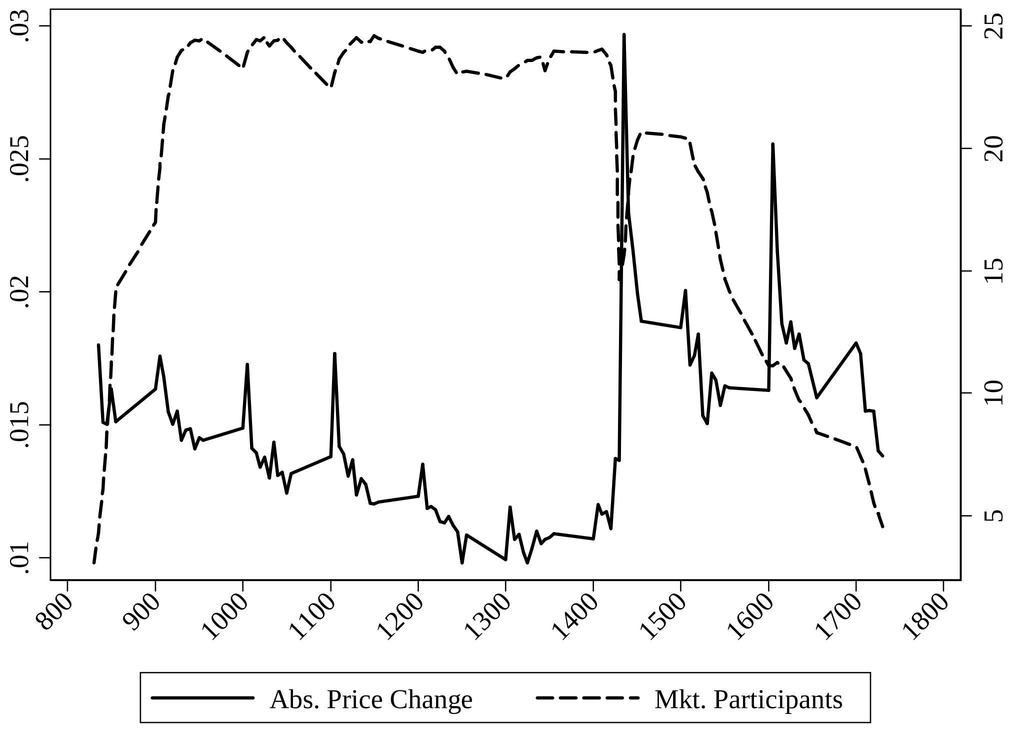
Note: Five minute data are averaged over the whole sample of the on-the-run 10 year BTPs. The depth measures that are not included in the figure show a similar pattern. The unit of measure is millions of euros.

Figure 6.3 – Steepness and Slope Measures



Note: Five minute data are averaged over the whole sample of the on-the-run 10 year BTPs. The DS and DSS exhibit a pattern that is very close to the slope one.

Figure 6.4 – Market Conditions



Note: Five minute data are averaged over the whole sample of the on-the-run 10 year BTPs. The left scale refers to the absolute price change measured in ticks and the right scale to the number of market participants.

6.2. Further investigation: The price impact approach

Although the descriptive analysis of the previous sections may provide an exhaustive picture of the Italian market liquidity, it is worthwhile to examine in a deeper way our price impact measures. As pointed out in section 4.2, a liquid market is a market where participants can rapidly execute large-volume transactions with a small impact on prices. In particular, we expect that buy-trades generate a positive impact and sell-trades a negative impact on prices. The intuition is that directional trades will be associated with a larger movement in prices when markets are illiquid. The price impact coefficient from the Kyle model relates net trading activity to price changes. Indeed, Kyle (1985) develops a dynamic model of insider trading to study the informational content of prices, the liquidity characteristics of a speculative market, and the value of private information to an insider. The model is able to characterize how an informed trader would transact in order to maximize the value of private information. The price impact coefficient in the model reflects how much the market adjusts prices to reflect the information content of trades and, as a consequence, it can be used to characterize the liquidity of financial markets. Although the price impact does not measure directly the speed of convergence of prices after a trade, i.e. the resiliency of the market, it provides a measure of how much prices move in response to a trade. Following Fleming (2003), we now estimate on the whole sample four specifications of the model presented in section 3.30 in order to provide a general assessment of the liquidity of the Italian wholesale secondary Treasury security market.

Table 06.4 – Price Impact of Trades for the 10 year BTPs

Panel A

	(1)	(2)	(3)	(4)
net trading count	0.0018***		0.0030***	
net trading quantity		0.00023***	-0.0002**	
# buy				0.00162***
# sell				-0.00199***
constant	-0.00013	-0.00007	-0.00017	0.00023
N	16,493	16,493	16,493	16,493
Adjusted R^2	0.025	0.022	0.026	0.025

Panel B

	N	mean	sd	p25	p50	p75	min	max
price change	16,493	3.9E-05	0.027	-0.013	0	0.014	-0.314	0.212
net trading count	16,623	0.09	2.40	-1	0	1	-29	39
net trading quantity	16,623	0.44	17.12	-5	0	5	-250	280
# buy	16,623	1.05	1.64	0	1	1	0	39
# sell	16,623	0.95	1.59	0	1	1	0	33

Note: Panel A reports the results of five-minute price change regression on various measure of trading activity over the same time interval for the on-the-run 10 year BTPs. Price changes are computed using midquotes. Net trading count equals the number of buyer-initiated trades less the number of seller-initiated trades. Net trading volume equals buyer-initiated less seller-initiated volume and is measured in millions of euros. Number of buy (sell) is the number of buyer (seller) -initiated trades. The sample period is January 1st, 2004 to November 13th, 2006. The stars specify the significance of coefficients: * p<.05; ** p<.01; *** p<.001. Heteroskedasticity-consistent standard errors are computed when the model does not pass the test for homoskedasticity. Panel B reports summary statistics for the variables in the regressions.

Table 6.4 reports the results of the estimation procedure on the on-the-run 10 year coupon bonds[64]. In the first specification we regress price changes on the net number of trades. The regression coefficient is, as expected, positive and highly significant. The value of the coefficient is 0.0018, this means that about 6 contracts, net, move the price of 1 tick, i.e. of 0.01. The adjusted R^2 is about 0.025, meaning that just 2.5% of the variation in price changes is explained by the net trading count. The adjusted R^2 statistics are in general low if compared with the Fleming (2003) ones. D'Souza et al. (2003) find comparable value for these statistics[65]. In specification (2) the independent variable is the net trading volume, the coefficient is still positive but is lower in magnitude and in explanatory power with respect to specification (1). The coefficient indicates that we need about 43 millions of euros, net, to move the price of 1 tick[66]. In specification 3 we include both the net number and the net size of the trades. In this case the coefficient of the net trading quantity is negative. Hence controlling for the number of trades, higher volume is associated with lower price changes. This is consistent with Fleming (2003) findings. In the last specification we use the number of buy and sell trades as regressors, we find similar coefficients but with the expected opposite signs. The results are amplified in magnitude if we consider off-the-run securities, in particular the constants are also significant and the explanatory power raises to about 4%. This seems to confirm that the market for off-the-run securities is less liquid with respect to the on-the-run one.
The estimation of the models is repeated for all the securities in the sample using yields changes instead of price changes as dependent variable. The results are displayed in Table 6.5, we report only the coefficients from specification (3). The estimation results for specifications (1), (2) and (4) are included in the Appendix C.

Table 06.5 – Price impact coefficients for all the maturity segments

	BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
net trading count	0.01696***	0.00864***	0.01467***	0.02051***	0.01372***	0.05708***
net trading quantity	-0.00205**	-0.00044*	-0.00041	-0.0007**	-0.00068***	-0.0003
constant	-0.00286*	-0.00038	-0.00165	-0.00002	-0.00091	-0.01936*
N	3,527	15,600	8,792	11,745	14,542	1,301
Adjusted R^2	0.065	0.026	0.039	0.059	0.040	0.198

Note: The table reports the results of five-minute yield change regression on various measure of trading activity over the same time interval for on-the-run Treasury securities. Yield changes are computed using information about closing prices and modified durations. Net trading count equals the number of buyer-initiated trades less the number of seller-initiated trades. Net trading volume equals buyer-initiated less seller-initiated volume and is measured in millions of euros. The stars specify the significance of coefficients: * p<.05; ** p<.01; *** p<.001. Heteroskedasticity-consistent standard errors are computed when the model does not pass the test for homoskedasticity.

The coefficients, when significant, have the expected signs. The magnitude of the relationships is higher for the less liquid segment, i.e. the index linked BTPs. This is not surprising and overall we can say that the 10 year index liked coupon bonds are characterized by lower trading activity and that trading activity, when occurs, have an impact on prices. The coefficients of net trading quantity are less significant than the coefficients on the net number of trades. For the very long segment of coupon bonds we observe a coefficient on the number of trades that is not very distant to the other BTPs, but we also find the highest coefficient for the size variable. This is probably due to the fact

[64] The estimation results for all the securities in the sample is included in the Appendix C.
[65] We computed the net trading count price impact coefficients in terms of prices in order to make a comparison among MTS Italy, US interdealer broker market, as in Fleming (2003), and Canadian interdealer broker market, as in D'Souza et al. (2003). The comparison, based on on-the-run 10 year bonds, shows a good degree of liquidity of MTS. The US and Canadian price impact coefficients are respectively two and seven times the coefficients estimated on MTS data.
[66] Interestingly, the estimated price impact is quite similar to the average value of the slope, which measures, in the order book, how far a trader has to move from the best quote, if he wants to trade € 100 mln.

that trading in 30 year BTPs is characterized by non frequent contracts of small size and as a result low trading volume. The adjusted R^2 statistic seems to be a negative function of liquidity, it ranges from the 2.6% of the 10 year BTPs to the 19.8% of the index linked BTPs.

Our estimates of the price impact coefficient add to a wide literature on the information content of the order flows[67]. It would be interesting to extend and deepen our analysis by comparing the price disclosure process on different securities and by evaluating the role of order book variables on the process.

6.3. Comparison between Liquidity Measures

In the previous paragraphs we presented the summary statistics for a large set of liquidity measures. We now want to show the mutual relationships among different measures, their reciprocal consistency, their reaction to market conditions. In order to do that, we computed the correlation coefficents among measures at 5-minute frequency and at weekly frequency. We included in the analysis the weekly estimation of the price impact coefficients. The correlation analysis will allow us, first, to better understand the degree of liquidity of the order book, second, to select a list of indicators that give a comprehensive description of the most important features of order book and trading data. The selection will follow the criteria specified in Fleming (2003): A liquidity measure should directly quantify the transaction costs, it should behave consistently with market participants' view about liquidity, it should be easy to calculate and be available on a real-time basis.

Table 6.7 and Table 6.8 at the end of the section contain correlation coefficients for measures respectively at a 5-minute and at weekly frequency for the on-the-run 10 year BTPs[68]. As in Fleming (2003) we include the set of trading measures only in the table at weekly frequency. We do not include them in the table at daily frequency because trade measures have a smoother behaviour at weekly frequency. Summary statistics at weekly frequency of all the measures used in the correlation analysis are reported in Table 6.6.

The presentation of the empirical evidence will follow a triangular structure, which is analogous with the structure of any matrix of correlation coefficients. We will first present the reciprocal correlation among market condition indicators. Second, we will comment the reciprocal correlations among tightness indicators, and their correlations with market condition indicators. Afterwards, we will show the reciprocal correlations among depth indicators, and their correlations with market condition and tightness indicators. Subsequently, we will focus on the correlation between breadth indicators and market condition, tightness and depth indicators; and so on. In other words, any time we comment a new class of indicators, we analyse the correlation of those indicators with the ones previously presented.

Market conditions

We will analyse the correlation of all our liquidity measures with two indicators of market conditions. This will allow us to evaluate the reaction of the order book and of trading activity to changes in the trading environment. The two indicators we will focus on are price volatility and the number of market participants. The former indicator mainly catches the process of price discovery. When news hit the market, they are incorporated in the prices and cause an increase of price volatility. In this process, asymmetries of information can have a central role and determine the behaviour of traders and market makers. A large literature on price discovery in the presence of

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[67] See, among other, Cheung, de Jong and Rindi (2005), Brandt and Kavajecz (2004), Green (2004).
[68] The tables for the remaining securities are available on request.

asymmetric information has shown that trading data, in particular order flows, convey information and contribute to determine prices. On the contrary, the role of order book data in the process of price discovery has not been explored to a great extent[69]. Investigating the connection between order book and price discovery is beyond the scope of the present research. However, our correlation analysis can be considered as a preliminary step towards further research. In this framework, we will be unable to identify casual relationships. Nevertheless, our descriptive analysis will allow us to highlight interesting co-movements among order book data, trading data and price volatility.

The number of market participants, that is the number of market makers present on the market, is considered by us as an additional indicator of market conditions, in particular it would measure the degree of competition among market makers. Therefore, we are interested in checking how the liquidity measures react to a variation in market competition. We are aware, however, that both the number of market participants and price volatility can not be considered as exogenous variables which affect order book data from outside. In effect, the decision of the dealers to participate to the market is taken together with the decisions on their proposals about prices and quantity. Therefore, the interpretation of the number of participation is not unambiguous. It is not only an indicator of market competition, but also an endogenous variable. The endogeneity of the number of participants is confirmed by its negative correlation, -0.23, with price volatility at 5-minute frequency. In periods of high volatility, when asymmetric information is presumably higher, some market makers temporarily leave the market in order to reduce the risk of adverse selection[70]. This pattern is clearly shown in Figure 6.4. Furthermore, price volatility depends on trading activity, as mentioned above, and, therefore it is an endogenous variable. However, we will consider it as an indicator of uncertainty on the true value of the security.

Tightness
As to the reciprocal correlations among the three measures of spread, a strong correlation is detected between spread and weighted spread. On the contrary, best spread show a smaller correlation with the other two measures.

We now focus on the connections between tightness measures and market condition indicators. The increase in price volatility makes spreads larger. Information uncertainty turns the market makers more cautious. The effect is particularly evident on weekly data. Evidently, price volatility modifies the behaviour of market makers especially when is persistent. Furthermore, when the number of market participants rises, best spread and weighted spread show a fall, which is particularly evident in the former case. This is true even on weekly averages and, therefore, it is not caused by the variability of the number of operators along the day. Evidently, the number of participants is truly a measure of market competition. On the contrary, only weak correlation is detected between spread and number of market participants at 5-minute frequency. We will later elaborate about the difference between the three measures of spread.

Depth
Total quote size is positively correlated with all the other measures of size. However, the correlation it is very high only with second size, average size and weighted depth. At 5-minute frequency, the

[69] Campbell and Hendry (2007), Mizrach and Neely (2005), Green (2004), Brandt and Kavajecz (2004) examine the price discovery process on the US government security market. Cheung, de Jong and Rindi (2005), Menkveld, Cheung and de Jong (2005), Beber, Brandt and Kavajecz (2007) study the price discovery process on the euro sovereign debt market. Fleming and Mizrach (2007) explore the role of order book data on the price discovery process on the US government security market.

[70] At weekly frequency the correlation is smaller and not statistically significant. Evidently, the decision of leaving the market is always temporary.

correlation between best size and total size is 0.45, while the correlation between second size and total size amounts to 0.83 and the correlation between total size and rest of the book is equal to 0.63. Evidently, when quote size changes, its variations are not uniformly distributed on the order book[71]. Furthermore, both at 5-minute frequency and at weekly frequency best and worst size are negatively correlated. This confirms that quote size is not uniformly distributed, and makes it interesting to explore the divergent behaviour of best and worst size.

Before examining the correlations of depth measures with the other indicators, the peculiar behaviour of quote size per operator has to be stressed. At 5-minute frequency the quote size per operator is either weakly and positively correlated or uncorrelated with the other measures of quote size. This confirms the evidence we commented in the previous section: the amount quoted by each dealer is quite stable; most of the variability of total quote size comes from the number of dealers who participate in the market. At weekly frequency, however, quote size per participant is highly and positively correlated with all the other measures of size. Evidently, the amount quoted by each market maker is quite stable during the day, but, in the more liquid weeks, all the quote size indicators become larger[72].

We now turn to examine the relationships between size measures and other indicators. First, at 5-minute frequency when price volatility increases all the quote size measures worsen but the quote size per operator. Therefore, as expected, a jump in price uncertainty causes a rise in spreads and a fall in quote size. However, the impact of volatility on the order book is only temporary. In effect, on weekly data no clear evidence of correlation between volatility and trade measures is present. Second, all the size measures are highly correlated with the number of market participants but the quote size per participant. Once again, this confirms that the number of participants explain most of the variability of quote size.

The analysis of the correlation between depth measures and best spread casts new light on the quality of the order book and on the distribution of quote size. At weekly frequency, best spread is negatively correlated with all the measures of size. This shows the consistency between best spread and size measures: When best spread shows higher market liquidity, quote size measures point to the same direction. However, data at 5-minute frequency hide a surprise: The correlation between best size and best spread becomes positive[73]. This means that when the market becomes more liquid and quote size increases and best spread shrinks, quote size at the best prices falls. Therefore, the behaviour of best size is peculiar: It is not strongly correlated with total quote size and it is inconsistent with best spread.

Finally, the correlations between depth measures and the other two measures of spread tell us something interesting about the differences among spread measures. At 5-minute frequency the correlations between weighted spread and total quote size is small, the correlation between weighted spread and best size has the opposite sign with respect to the correlation of best spread, and the correlation between spread and all the size measures are close to zero. In order to give an explanation to the peculiar behaviour of spread and weighted spread, we will go back to it later, after elaborating about steepness.

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[71] See note 52 for similar evidence, based on the comparison between hours of trade concentration and rest of the day. However, a low correlation coefficient between total quantity and best size is found even in the hours of trade concentration.

[72] Notice, however, that most of the variability of size measures is concentrated at 5-minute frequency. Table 5.6 shows that the coefficient of variations at weekly frequency of quote size amounts to 0.11, whereas at 5-minute frequency the same coefficient was 0.40.

[73] The positive correlation is not caused by the evolution of the two measures throughout the day. The correlation becomes even larger in the hours of trade concentration.

Breadth
In the previous section we already pointed out that the behaviour of steepness during the day is at odds with the behaviour of spread and size measures. Correlation analysis confirms it: Steepness increases when best spread falls and quote size rises. Steepness is not consistent with the other measures of liquidity. What drives steepness? How can the rise of steepness at moments when the market seems to be more liquid be explained? The analysis of simple correlations provides interesting insights, even though it does not allow to answer thoroughly those questions. A multivariable econometric approach could be very helpful. 5-minute frequency data shows relevant correlation of steepness with the number of market makers, 0.51, with total quote size, 0.48, and, what is more, with worst size, 0.73. That evidence seems to be connected with the evolution of the order book during the day: in the hours of trade concentration, when the number of market makers increases, quote size increases, but it is not distributed uniformly over the quotes. On the contrary, the off-the-best quotes are the most affected by the additional quote size. Furthermore, new quotes are added at end of the order book, and this makes the order book steeper.

The correlation of steepness with quote size and number of market makers is strongly connected to the evolution of the order book throughout the day. In effect, on weekly data those correlations disappear. However, when the attention is focused only on the hours of trade concentration, another interesting evidence comes out: The correlation of steepness with quote size and market participants is low, as expected. However, a strong negative correlation with best spread, -0.54, and best size, -0.43, emerges, along with a strong positive correlation with worst size, 0.64. This seems to confirm what we already pointed out about low quality of the order book. In the hours of trade concentration, the tightening of best spread is not accompanied by an increase in best size. On the contrary, best size is reduced, the order book becomes steeper and the quantities available for trade are moved to the end of the order book.

Finally, we come back to the differences among different measures of tightness. The peculiar behaviour of steepness and the low quality of the order book help us to find an interpretation of those differences. Both at 5-minute and at weekly frequency simple spread and weighted spread have a large and positive correlation with steepness. When steepness increases, and at the same time best spread shrinks, the other two measures of spread rise. Behind the inconsistent behaviour of spreads there is simple algebra. The computation of both spread and weighted spread draws on all the quotes in the order book: The simple spread is the difference between the average of bid quotes and the average of ask quotes; weighted spread is the difference between the weighted average of those quotes. As a consequence, if steepness increases and best spread does not move, both the simple and the weighted average of bid quotes fall and, at the same time, both the simple and the weighted average of the ask quote rise. This explains the algebraic positive relationship of steepness with both spread and weighted spread[74]. In the end, the divergent behaviour of the spread measures can be interpreted as the outcome of what we called the low quality of the order book: As the best spread tightens and total size increases, best size falls and the order book becomes steeper. And the steeper order book causes a jump of simple and weighted spread.

Slope
Our expectations about the behaviour of slope measures were mixed. On one hand, slope is a measure of liquidity. Namely, the smaller the slope, the more liquid the market. On the other hand,

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[74] Actually, the link between spreads and steepness is complicated by the evidence of a negative correlation between best spread and steepness. Therefore, as steepness rises, simple and weighted spread are affected by two opposite effects: On one hand, the best spread fall tends to shrink them; on the other hand, the steepness rise enlarges them. Evidently, the latter effect prevails on the former one.

given that steepness appears at the numerator of slope[75], we could expect that slope could follow the same pattern as steepness and show an inconsistent behaviour with respect to other measures of liquidity. As a matter of fact, the evidence from correlation analysis shows that slope does not follow the same pattern as steepness. In effect, the correlation between steepness and slope is negative, slope behaves consistently with the other measures of liquidity and it decreases when best spread tightens, or when total quote size and best size increase. Furthermore, the increase of the number of market makers causes the slope to drop, as the other liquidity measures do; and when price volatility rises, slope tends to rise as well, at least at 5-minute frequency.

As to the differences among slope, DS and DSS, our evidence shows their similar correlation coefficients. Given that slope is easier to compute and it is available on a real-time basis, we definitively prefer it to the others.

Market quality index and CRT

Both market quality index and CRT turn up to be good synthetic indicators of market liquidity. They show the expected correlation with spreads, quote size measures, slope, market participants and volatility, even though the effect of volatility on liquidity is only temporary, as usual. Furthermore, they are reciprocally consistent: When market quality index improves, the cost of round drip falls.

The unique contradictory correlations of CRT and market quality index are the ones with best spread and with steepness. But this is not surprising after what we wrote about the low quality of the order book. CRT shows a positive correlation with best size at 5-minute frequency. This means that when best size rises the cost of round trip increases, and the two liquidity indicators point at different directions. The evidence has reasonably to be related to the positive correlation between best size and best quote: Given that larger best size causes a larger best spread, a positive correlation between best spread and CRT turns out. In effect, at weekly frequency, when the correlation between best spread and best size changes sign, the same occurs to the correlation between CRT and best size.

Furthermore, at 5-minute frequency market quality index is only slightly correlated with steepness, and this is good, given that steepness does not behave as a liquidity measure. However, CRT is negatively and quite strongly correlated with steepness, and this adds up to the previous evidence about contradictory outcomes of steepness with respect to other liquidity measures. At weekly frequency, however, a switch occurs and CRT shows almost no correlation with steepness and, on the contrary, market quality index exhibits a strong negative correlation.

Trading measures

Trading measures show the expected reciprocal correlations. A larger trade volume is combined with larger turnover and smaller price impact coefficients[76]. Furthermore, trade size confirms to be quite constant and not very affected by market evolution: It is not significantly correlated with trading volume. As a consequence, trading frequency is highly correlated with trading volume. However, the relevant issue is: Are the trading measures consistent with order book measures?

No clear and general relationship emerges between trading and order book measures. For instance, trading volume and trading frequency have no significant correlation with spread measures. However, an increase in trading frequency or in turnover has a negative impact on most of the quote

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[75] The other two measures close to slope, DS and DSS, exhibit an algebraic direct relationship with steepness as well.

[76] On the off-the-run securities, though, the correlations between trade volume and price impact coefficients are small and not significantly different from nil.

size measures, the number of market participants, the steepness and the slope of the order book, the market quality index[77]. On the contrary, an increase in trade size or a fall in the price impact coefficients is combined with tighter spreads, larger quote size and market participants, reduced steepness and slope, a higher market quality index.

In the end, trading measures can be split in two groups: The first group comprises trading volume, trading frequency, turnover. They either show no correlation with order book measures, or are combined with less liquid order book. The second group comprises trade size and price impact coefficients. They move in the same directions as the other liquidity indicators.

Table 6.6 – Weekly Summary Statistics

	N	**mean**	**sd**	**p25**	**p50**	**p75**	**min**	**max**
best spread	145	0.025	0.002	0.023	0.025	0.026	0.020	0.034
spread	145	0.049	0.003	0.047	0.049	0.051	0.042	0.063
weighted spread	145	0.046	0.003	0.044	0.045	0.048	0.040	0.060
best size	145	37.10	5.64	34	37.7	41	19.5	50
second size	145	74.98	12.02	68	75.1	83.0	34.25	101
worst size	145	46.49	9.85	39.1	47	54	17	73
quote size	145	156.45	16.94	147.2	158	167	98	200
average quote size	145	45.25	6.03	41.3	46	49	23.78	58.6
weighted depth	145	88.38	10.69	82.31	90.19	95.55	49	115.5
qte size per partic.	145	8.16	0.58	7.77	8.10	8.42	7	10.4
steepness	145	0.03	0.00	0.02	0.03	0.03	0.02	0.03
slope	145	0.03	0.00	0.03	0.03	0.03	0.02	0.1
DS	145	3.50	0.67	3.05	3.29	3.76	2.55	7.14
DSS	145	0.0004	0.0001	0.0003	0.0004	0.0004	0.0003	0.001
mkt quality index	145	9.41	1.65	8.18	9.64	10.41	3.94	13.13
CRT 10	145	0.03	0.00	0.02	0.02	0.03	0.02	0.03
abs price change	145	0.01	0.00	0.0129	0.01459	0.01604	0.00831	0.023
mkt participants	145	19.26	1.56	18.61	19.43	20.33	13.71	22.26
trade size	145	6.50	0.47	6.11	6.52	6.91	5.45	7.49
trading volume	145	368.91	128.44	281.68	355.54	446.47	99.84	678.91
trading frequency	145	56.60	19.70	40.88	55.17	68.69	16.38	106.41
turnover ratio	145	3.36	2.20	1.81	2.61	4.25	0.55	12.65
NTQ	145	0.0003	0.0003	0.0002	0.0003	0.0005	-0.0006	0.0014
NTC	145	0.0025	0.0021	0.0011	0.0021	0.0037	-0.0033	0.0101

Note: The table report summary statistics for the 10 year on-the-run BTPs' database at a weekly frequency. NTQ and NTC are the price impact coefficients coming from weekly regression of five-minute price change on respectively the net trading quantity and the net number of trades over the same time interval. Price changes are computed using midquotes and are measured in terms of prices. "p" is the p-th percentile of the distribution.

[77] No significant correlation is found between trading frequency and order book measures on the off-the-run securities, though.

Table 6.7 – Correlations at a 5-minute frequency

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*	*DS*	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*
best spread	1																
spread	0.6789*	1															
weighted spread	0.7019*	0.8433*	1														
best size	0.1988*	0.1799*	-0.1382*	1													
second size	-0.2475*	-0.0041	-0.1857*	0.2479*	1												
worst size	-0.6980*	-0.0224*	0.0814*	-0.2026*	0.3168*	1											
quote size	-0.4081*	0.0142*	-0.1626*	0.4471*	0.8523*	0.6334*	1										
average quote size	-0.2301*	-0.1177*	-0.2230*	0.6094*	0.8258*	0.3165*	0.8908*	1									
weighted depth	-0.1949*	0.0765*	-0.1897*	0.7479*	0.7791*	0.3126*	0.9215*	0.9302*	1								
qte size per partic.	-0.1121*	-0.1882*	-0.2258*	0.1124*	0.0661*	-0.0176*	0.0886*	0.1395*	0.1161*	1							
steepness	-0.5697*	0.3900*	0.1986*	-0.1603*	0.2659*	0.7279*	0.4770*	0.0566*	0.2311*	-0.1397*	1						
slope	0.4177*	0.1513*	0.1907*	-0.2247*	-0.6315*	-0.4322*	-0.6863*	-0.6526*	-0.6054*	-0.1165*	-0.3048*	1					
DS	0.2875*	-0.0377*	0.1673*	-0.2888*	-0.6422*	-0.3955*	-0.7092*	-0.6355*	-0.6498*	-0.0644*	-0.3447*	0.6480*	1				
DSS	0.3390*	0.1187*	0.2204*	-0.2180*	-0.5723*	-0.3507*	-0.4857*	-0.4698*	-0.4541*	-0.2593*	-0.2274*	0.7650*	0.6532*	1			
mkt quality index	-0.3188*	-0.3264*	-0.3204*	0.4603*	0.7596*	0.3132*	0.7939*	0.9491*	0.7978*	0.1768*	-0.0659*	-0.6242*	-0.5625*	-0.4393*	1		
CRT 10	0.9666*	0.5479*	0.5935*	0.2100*	-0.2847*	-0.6710*	-0.4433*	-0.2434*	-0.2134*	-0.0741*	-0.5355*	0.4615*	0.3114*	0.3473*	-0.3428*	1	
abs price change	0.1401*	0.0502*	0.1139*	-0.1069*	-0.1755*	-0.1174*	-0.2190*	-0.1973*	-0.2064*	-0.0028	-0.0932*	0.1565*	0.1452*	0.1383*	-0.1793*	0.1252*	1
mkt participants	-0.4006*	0.0403*	-0.1308*	0.4184*	0.8243*	0.6278*	0.9724*	0.8542*	0.8882*	-0.0930*	0.5066*	-0.6744*	-0.7015*	-0.4648*	0.7478*	-0.4257*	-0.2251*

Note: The table reports correlation coefficients for the 10 year on-the-run BTPs. The measures are calculated at a 5-minute frequency. The * indicates that the correlation coefficients are significant at the 5% level or better.

Table 06.8 – Weekly Correlations

	best spread	*spread*	*weigh. spread*	*best size*	*second size*	*worst size*	*quote size*	*aver. qte size*	*weigh. depth*	*qte size per partic.*	*steepness*	*slope*
best spread	1											
spread	0.6148*	1										
weighted spread	0.7115*	0.9262*	1									
best size	-0.2862*	-0.5840*	-0.7161*	1								
second size	-0.2266*	-0.6386*	-0.6501*	0.7891*	1							
worst size	-0.3014*	0.3863*	0.3460*	-0.2828*	-0.2874*	1						
quote size	-0.4602*	-0.4287*	-0.5094*	0.7325*	0.8041*	0.2972*	1					
average quote size	-0.2601*	-0.6979*	-0.6513*	0.8185*	0.9514*	-0.2072*	0.8286*	1				
weighted depth	-0.3859*	-0.5724*	-0.6608*	0.9031*	0.9089*	-0.0187	0.9430*	0.9235*	1			
qte size per partic.	-0.2900*	-0.3160*	-0.3523*	0.5828*	0.5767*	0.2350*	0.7382*	0.6258*	0.7046*	1		
steepness	-0.1091	0.6874*	0.5154*	-0.5127*	-0.5911*	0.6968*	-0.1701*	-0.6540*	-0.4066*	-0.2202*	1	
slope	0.4296*	0.6293*	0.5928*	-0.6443*	-0.7377*	-0.0864	-0.7922*	-0.8184*	-0.7956*	-0.5863*	0.4499*	1
DS	0.3591*	0.6220*	0.6628*	-0.7450*	-0.8423*	0.105	-0.7882*	-0.8420*	-0.8522*	-0.4915*	0.4468*	0.8797*
DSS	-0.3338*	-0.149	-0.1896*	0.0426	-0.0766	0.1847*	0.0718	-0.0295	0.0353	0.1271	0.103	-0.0876
mkt quality index	-0.3868*	-0.8362*	-0.7673*	0.7856*	0.8879*	-0.2760*	0.7323*	0.9533*	0.8498*	0.6024*	-0.7394*	-0.7875*
CRT 10	0.9507*	0.5768*	0.6759*	-0.3087*	-0.2013*	-0.3298*	-0.4590*	-0.2470*	-0.3865*	-0.3764*	-0.0495	0.4449*
abs price change	0.3082*	0.2579*	0.3393*	-0.1171	-0.0072	0.1602	0.0422	0.0107	-0.0229	0.0938	-0.0217	-0.0483
mkt participants	-0.4130*	-0.3659*	-0.4576*	0.5653*	0.6660*	0.1850*	0.7876*	0.6518*	0.7489*	0.1819*	-0.0855	-0.6685*
trade size	-0.0896	-0.3025*	-0.2956*	0.5163*	0.5849*	-0.0057	0.5724*	0.6010*	0.6002*	0.5951*	-0.3326*	-0.5021*
trad volume	-0.1266	-0.0173	-0.0527	-0.0331	-0.1182	0.043	-0.0672	-0.1092	-0.0722	0.0383	0.1091	0.0678
trad frequency	-0.102	0.0411	0.0101	-0.1670*	-0.2464*	0.0195	-0.2144*	-0.2473*	-0.2221*	-0.1305	0.1918*	0.1928*
turnover	-0.1242	0.2961*	0.3164*	-0.4791*	-0.5187*	0.4149*	-0.2781*	-0.4752*	-0.4273*	-0.0987	0.5008*	0.3270*
NTQ	-0.0787	0.1714*	0.1654*	-0.1849*	-0.2119*	0.3040*	-0.0328	-0.1912*	-0.1326	0.0796	0.2401*	0.0635
NTC	-0.0833	0.1539	0.1482	-0.1404	-0.1609	0.3237*	0.0299	-0.1345	-0.0737	0.1309	0.2143*	0.017

	DS	*DSS*	*mkt qual ind*	*CRT 10*	*abs price change*	*mkt partic.*	*trade size*	*trad volume*	*trad freq.*	*turnover*	*NTQ*	*NTC*
DS	1											
DSS	0.009	1										
mkt quality index	-0.7671*	0.0378	1									
CRT 10	0.3179*	-0.3660*	-0.4080*	1								
abs price change	0.0446	-0.1392	-0.0527	0.2557*	1							
mkt participants	-0.7498*	-0.0172	0.5386*	-0.3410*	-0.0078	1						
trade size	-0.4890*	0.1261	0.5603*	-0.1621	0.1613	0.3052*	1					
trad volume	0.0532	-0.0189	-0.0827	-0.1044	0.01	-0.1441	0.1258	1				
trad frequency	0.1572	-0.0415	-0.2194*	-0.0404	-0.0509	-0.2100*	-0.1099	0.9626*	1			
turnover	0.4538*	0.152	-0.4451*	-0.0797	0.0421	-0.3447*	-0.1997*	0.4039*	0.4601*	1		
NTQ	0.1537	-0.0091	-0.1810*	-0.1234	0.1800*	-0.1234	-0.2138*	-0.3607*	-0.3423*	-0.0323	1	
NTC	0.1075	0.0401	-0.132	-0.1317	0.2409*	-0.0808	-0.1182	-0.3638*	-0.3663*	-0.0502	0.9700*	1

Note: The table reports correlation coefficients for the 10 year on-the-run BTPs. The measures are calculated weekly. The * indicates that the correlation coefficients are significant at the 5% level or better.

6.4. Liquidity Comparison Across Securities

In this section we perform a direct comparison of the liquidity across the securities in the sample. We focus on the on-the-run issues[78]. Since many measures are function of prices we need to exploit the relationship between prices and duration[79] to express these measures in yields. By doing so we make securities with different maturities reciprocally comparable. Conversely, the measures that depend only on the quote quantities can be compared directly. In particular, *best spread*, *quoted spread*, *weighted spread, steepness*, *slope*, *DS* e *DSS* and *absolute price change* are divided by the product between the daily closing modified duration and the daily closing price. *Market quality index* is now simply the ratio between the *average quote size* and the yield version of the *spread*, and price impact coefficients, *NTQ* and *NTC*, have been estimated once again, computing the dependent variable in terms of yields. We work out both summary statistics and correlation coefficients at weekly frequency.

6.4.1. Summary statistics

In the tables at the end of the section we compare the liquidity measures across the different maturity segments. We start by commenting the market condition measures. Market volatility ranges from 0.0013 for the CTZs to the 0.002 for the 5 year BTPs. The number of market participants goes from 8.8 in the case of 10 year index linked BTPs, to 19.3 in the case of 10 year BTPs. CTZs and 30 year BTPs are in lower side of the range.

With respect to best spread, the 10 year BTP is the most liquid security, followed by CTZs, 5 year BTPs, 30 year BTPs and 3 year BTPs. The 10 year index linked BTPs have the wider spread, and, in general, they have the worst performance whatever measure we consider. Surprisingly, the 30 year BTPs gains the fourth position. This result is robust if we look at the median of the distributions.

Turning to the depth measures, we note that the medium and long term BTPs quote larger quantities in the first two levels of the book and smaller in the rest of it. The very long term BTPs, the zero coupon bonds and the index linked bonds exhibit an opposite pattern and in general they have a lower *quote size*. Therefore, the less liquid segments have a *quote size* that is comparable to the most liquid segments, but the distribution of depth is more concentrated in the lower part of the book. This implies that *quote size* alone is not a good proxy of liquidity and we have to consider the quantity position in the book. Focusing on the medium and long term BTPs, namely BTP3, BTP5 and BTP10, the peculiar behaviour of depth measures turns up. Although the amount of quote size is comparable among the three securities, average quote size and quote size per participant is higher the shorter the maturity. On BTP3 the number of market participants is smaller than on BTP10, however each of them, on average, posts an amount higher than the amount posted on BTP10. Furthermore, the average quote size is higher on BTP3 then on BTP10, and both best size and second size are larger on BTP3 than on BTP10. In all the previous cases BTP5 falls between BTP3 and BTP10. The evidence adds up to what we called the low quality of the order book. On the long side of the BTP market, tighter spreads are associated with smaller size on the top of the book, smaller quote size per market participant, smaller average quote size.

We included in our analysis the *quote frequency*, which is the number of different prices quoted[80] (Table 6.12). *Quote frequency* can be interpreted as a measure of market breadth. In the medium and long term segment for the BTPs we find, on average, three quotes. This implies that the whole

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[78] In the Appendix C we include the statistics for the off-the-run issues.

[79] We use daily data on the modified duration provided by Bloomberg and Reuters.

[80] Quote frequency matches with quote frequency in D'Souza and Gaa (2004) and corresponds to $\frac{n_{ask}+n_{bid}}{2}$.

market is visible to each market participant through the MTS page that reports the best five quotes and the corresponding quantities. On the contrary, in the very long term BTP segment, i.e. the 30 year one, we have around two times the quotes of the other BTPs. Furthermore, the CTZs show on average 10 different quotes; hence, only half of the market is visible. The larger quote frequency for the CTZs is partly explained by the pricing conventions. In fact, the CTZs are quoted in tenths of a point, while all the other securities in our sample are quoted in points, where a point equals one per cent of par[81]. Evidently, a smaller tick size increases the quote frequency. However, quote frequency does not depend only by pricing conventions. The 10 year index linked BTPs are quoted in hundredths of one per cent of par, nevertheless, they also show a high *quote frequency*. Therefore, a high *quote frequency* also gives evidence of a lack of competition among market makers.

From the perspective of steepness, slope, DS and DSS, the 10 year BTPs show always the lower values and then the higher liquidity. The 30 year BTPs confirm their good performances in that they have the second lowest *steepness* and *slope*. The zero coupon and the index linked bonds achieve the worst values, this is partly due to their less concentrated book. In general, these measures provide similar information. It is interesting to note that the *steepness*, that in the previous sections we proved to be not a good proxy of liquidity, behaves correctly in the univariate case, that is, it is smaller for the most liquid securities. This is an indirect proof of the importance of the correlation analysis as a tool to distinguish the most informative measures of liquidity. The last measure in the table is a variation of the *market quality index*, and we call it *market quality index 2*. In particular at the numerator we substitute the *average quote size* with the *quote size*. The aim of the new measure is to allow a better comparison of market quality index across securities. In effect, CTZs are characterized by larger quote frequency, and, as a consequence, smaller *average quote size* and smaller values of the usual *market quality index*. The 10 year BTPs show the higher value of *market quality index 2*, followed by the 5 year and the 3 year BTPs. The 30 year BTPs and the CTZs show values of the index that are one third of the 10 year ones. The index linked bonds perform even worse.

Let us finally consider our measures of trading. As expected the 10 year BTPs show the best performances in terms of volumes and contracts. Moreover, trading in these securities produces a low impact on prices. This point is particularly evident: trading in the 5 year and 3 year BTPs produces price impacts that are twice the 10 year BTPs ones. The difference with respect to the other securities is even larger. The 3 year BTPs are characterized by contracts that are less frequent but with higher mean *trade size* and higher price impact with respect to the 10 year and 5 year BTPs. CTZs are traded frequently and with small trade size, this could be a signal of the fact that this kind of securities is considered as a monetary instrument. The other trading variables exhibit values, in the case of CTZs, that are close to the ones shown by medium and short term BTPs. The 30 year BTPs are traded twice as frequently as the 10 years index linked BTPs are, but for half of the size. As a result *trading volume* and *turnover* ratio are very similar for those segments. The index linked securities are the less traded, and they show price impact coefficients that are between six and seven times the 10 year BTPs ones.

To sum up, the medium and long term BTPs seem to represent the most liquid segments. As for the variables that exploit order book information, the 10 year BTP is the most liquid security with respect to spread and steepness measures. It is also the most active segment of the market. However, it has not the higher quote size on the top of the book and on average the 3 year and the 5 year BTPs seems to have larger depth. The CTZs have a good performance in terms of *best spread*, but they are characterized by a more dispersed book. The very long term BTPs show performances

[81] In other words, the minimum price difference, i.e. the tick, is 0.01 for the BTPs and 0.001 for the CTZs.

that are better than expected with respect to the order book measures. On the other hand, trading activity in this segment is still low and only the index linked bonds exhibit lower figures. This latter segment is not surprisingly the worst in terms of most of the employed measures.

Till now we have focused on the on-the-run securities. As a robustness check we now consider the difference between on-the-run and off-run securities. It turns out that this difference is always small[82]. In general, we have that the on-the-run securities show a higher liquidity in terms of order book measures. Indeed, these better performances are small in magnitude and they are clearer for the more complex measures that take into account both prices and quantities. The 5 year BTP is, among the most liquid BTPs, the security with higher variability in the comparative analysis. With respect to the trade measures, the liquidity is higher for the on-the-run securities and this pattern is clearer for the 10 year and 3 year BTPs. The 5 year BTPs and the CTZs show a higher mean trading volume when they are off-the-run. If we look at the median values this result holds only for the CTZs.

6.4.2. Correlation analysis

Following D'Souza et al. (2003) we work out the correlation coefficients among the segments. For the sake of exposition we present the results for a subset of our measures[83].

The absolute price change is, among all the measures, the one that shows the highest magnitude in the correlation coefficients. The coefficients are particularly high for the long and very long term segments. The participation in the market for the different segments is also positively correlated and significant.

Looking at the order book measures, we note that the 10 year BTPs are in general positively related with the other BTPs, the correlation coefficients are higher with the 30 year and 5 year BTPs for the spread and the slope variables and with the 3 year BTPs for the size measures. In general, the correlation coefficients are positive for the BTPs; this is consistent with the hypothesis of integration of these segments. However, as long as we consider the CTZs, we find negative and significant correlation coefficients between them and the 5 year BTPs in the spread measures and in the *quote size per participant*. The coefficients are negative, but not significant, if we look at *trading volume* and *trading frequency*.

The coefficients regarding the trading measures are always positive when significant, the relationships are stronger among the BTPs. This is consistent with the previous findings. The price impact measures more often exhibit significant correlations[84]. The index linked bonds are scarcely related to the other securities in the sample.

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[82] The tables regarding the off-the-run sample are included in Appendix C.
[83] The remaining tables are available in Appendix C.
[84] With respect to the variables not included in this paragraph, we can say that the *second size* and *quoted size* measures show positive and significant correlations. The *worst size* and the *quote size per participant* are positive when significant. The slope, DS and DSS measures seldom are significant.

Table 06.9 – Comparison of Market Condition Indicators across Securities

		# obs.	mean	sd	p25	p50	p75	min	max
absolute price change	*BTP 30*	102	0.0019	0.0003	0.0016	0.0018	0.0020	0.0011	0.0028
	BTP 10	139	0.0018	0.0003	0.0016	0.0017	0.0019	0.0010	0.0030
	BTP 5	132	0.0020	0.0005	0.0017	0.0020	0.0022	0.0012	0.0037
	BTP 3	153	0.0017	0.0003	0.0015	0.0017	0.0019	0.0011	0.0027
	CTZ	142	0.0013	0.0003	0.0011	0.0013	0.0016	0.0006	0.0021
	BTP 10 ind	82	0.0019	0.0003	0.0017	0.0019	0.0021	0.0012	0.0029
market particip.	*BTP 30*	102	10.65	1.06	10.07	10.75	11.34	7.07	12.44
	BTP 10	145	19.26	1.56	18.61	19.43	20.33	13.71	22.26
	BTP 5	134	17.02	3.07	14.59	17.18	19.76	8.18	22.21
	BTP 3	154	13.77	1.36	12.94	13.95	14.65	6.80	16.28
	CTZ	144	12.41	1.74	11.83	12.70	13.38	1.02	15.07
	BTP 10 ind	103	8.78	0.73	8.38	8.79	9.21	5.07	10.52

Note: The measures are calculated weekly as mean quote frequency, mean five-minute absolute price change and mean number of market participants of the on-the-run securities. “p” is the p-th percentile of the distribution.

Table 6.10 – Comparison of Tightness Measures across Securities

		# obs.	mean	sd	p25	p50	p75	min	max
best spread	*BTP 30*	102	0.0062	0.0009	0.0056	0.0062	0.0069	0.0043	0.0082
	BTP 10	139	0.0031	0.0003	0.0028	0.0030	0.0033	0.0024	0.0041
	BTP 5	132	0.0053	0.0008	0.0047	0.0052	0.0058	0.0041	0.0101
	BTP 3	153	0.0071	0.0010	0.0065	0.0070	0.0075	0.0052	0.0128
	CTZ	142	0.0042	0.0010	0.0034	0.0039	0.0047	0.0026	0.0074
	BTP 10 ind	82	0.0125	0.0021	0.0114	0.0125	0.0140	0.0080	0.0172
spread	*BTP 30*	102	0.0102	0.0011	0.0093	0.0101	0.0108	0.0082	0.0124
	BTP 10	139	0.0061	0.0004	0.0058	0.0061	0.0064	0.0053	0.0071
	BTP 5	132	0.0101	0.0010	0.0094	0.0098	0.0109	0.0081	0.0138
	BTP 3	153	0.0142	0.0015	0.0134	0.0142	0.0148	0.0115	0.0243
	CTZ	142	0.0131	0.0021	0.0114	0.0131	0.0144	0.0089	0.0216
	BTP 10 ind	82	0.0235	0.0020	0.0228	0.0240	0.0249	0.0188	0.0272
weighted spread	*BTP 30*	102	0.0098	0.0011	0.0089	0.0096	0.0104	0.0078	0.0123
	BTP 10	139	0.0057	0.0004	0.0053	0.0056	0.0059	0.0050	0.0067
	BTP 5	132	0.0093	0.0009	0.0087	0.0092	0.0101	0.0074	0.0118
	BTP 3	153	0.0135	0.0014	0.0125	0.0134	0.0140	0.0108	0.0227
	CTZ	142	0.0112	0.0017	0.0098	0.0110	0.0123	0.0080	0.0162
	BTP 10 ind	82	0.0239	0.0020	0.0232	0.0243	0.0253	0.0189	0.0268

Note: The measures are calculated weekly as mean best spread, mean quoted spread, mean weighted spread of the on-the-run securities. “p” is the p-th percentile of the distribution.

Table 6.11 – Comparison of Depth Measures across Securities

		# obs.	mean	sd	p25	p50	p75	min	max
best size	*BTP 30*	102	7.54	0.80	7.03	7.45	7.99	5.31	9.60
	BTP 10	145	37.10	5.64	33.64	37.69	41.15	19.53	50.34
	BTP 5	134	45.17	7.07	41.26	45.68	50.30	25.26	62.15
	BTP 3	154	52.24	9.96	45.93	53.28	59.39	20.53	75.69
	CTZ	144	10.28	3.87	8.40	9.96	11.23	5.73	48.25
	BTP 10 ind	103	10.76	1.18	9.93	10.61	11.27	8.58	14.81
second size	*BTP 30*	102	11.93	2.149	10.317	11.73	13.12	7.107	18.324
	BTP 10	145	74.98	12.02	68.15	75.11	83.02	34.25	101.04
	BTP 5	134	88.60	13.61	82.02	88.71	94.87	36.04	120.56
	BTP 3	154	96.03	13.41	88.36	96.99	104.3	26.22	129.49
	CTZ	143	12.61	4.14	10.12	11.99	13.94	6.56	28.12
	BTP 10 ind	103	13.81	1.902	12.641	13.67	14.94	10.38	23.22
worst size	*BTP 30*	102	66.18	8.50	62.54	67.35	71.41	37.43	82.55
	BTP 10	145	46.49	9.85	39.10	46.62	53.64	16.62	73.34
	BTP 5	134	23.54	5.80	19.45	22.34	27.44	11.24	38.56
	BTP 3	154	17.26	4.65	13.95	16.47	20.37	7.79	29.76
	CTZ	143	86.58	12.76	79.16	85.32	94.71	29.58	124.81
	BTP 10 ind	103	103.96	11.42	98.13	104.23	111.22	44.55	126.49
quoted size	*BTP 30*	102	82.68	9.95	78.27	83.50	89.93	53.04	98.28
	BTP 10	145	156.45	16.94	147.17	157.60	167.02	97.72	200.23
	BTP 5	134	155.12	18.66	146.18	155.25	165.95	79.71	199.29
	BTP 3	154	163.66	20.69	149.92	167.41	177.47	72.48	208.81
	CTZ	144	107.95	17.68	98.67	108.70	117.31	9.62	170.49
	BTP 10 ind	103	127.21	12.00	121.10	127.48	134.77	62.90	152.18
average quote size	*BTP 30*	102	11.61	1.20	10.97	11.61	12.53	7.83	14.40
	BTP 10	145	45.25	6.03	41.30	45.86	49.15	23.78	58.58
	BTP 5	134	52.90	8.71	47.45	53.60	58.62	26.22	74.50
	BTP 3	154	62.25	10.19	56.41	63.12	69.03	21.52	85.28
	CTZ	143	10.59	2.07	9.36	10.36	11.58	6.78	21.36
	BTP 10 ind	103	15.42	1.01	14.80	15.36	16.04	11.37	17.93
qtd size per participant	*BTP 30*	102	7.59	0.35	7.39	7.60	7.82	6.59	8.64
	BTP 10	145	8.16	0.58	7.77	8.10	8.42	6.58	10.41
	BTP 5	134	9.35	1.63	8.07	9.06	11.03	6.13	12.11
	BTP 3	154	11.91	0.68	11.59	11.93	12.30	9.58	13.92
	CTZ	143	8.92	1.08	8.17	8.80	9.63	6.79	13.32
	BTP 10 ind	103	14.42	0.57	14.10	14.46	14.79	11.91	15.52

Note: The measures are calculated weekly as mean beast size, mean second size, mean worst size, mean quoted size, mean average quote size, and mean quoted size per market participant of the on-the-run securities. “p” is the p-th percentile of the distribution.

Table 06.12 Comparison of Breadth and Multidimensional Measures across Securities

		# obs.	mean	sd	p25	p50	p75	min	max
steepness	*BTP 30*	102	0.0042	0.0008	0.0036	0.0041	0.0048	0.0030	0.0062
	BTP 10	139	0.0031	0.0003	0.0029	0.0031	0.0033	0.0022	0.0038
	BTP 5	132	0.0050	0.0005	0.0046	0.0049	0.0052	0.0039	0.0066
	BTP 3	153	0.0073	0.0008	0.0068	0.0073	0.0077	0.0056	0.0117
	CTZ	142	0.0113	0.0023	0.0096	0.0108	0.0124	0.0072	0.0204
	BTP 10 ind	82	0.0110	0.0017	0.0097	0.0106	0.0124	0.0075	0.0144
quote frequency	*BTP 30*	102	6.83	0.39	6.67	6.83	7.04	5.14	7.62
	BTP 10	145	3.46	0.25	3.31	3.49	3.63	2.69	4.18
	BTP 5	134	2.93	0.22	2.76	2.90	3.05	2.53	3.76
	BTP 3	154	2.70	0.19	2.57	2.67	2.76	2.32	3.43
	CTZ	144	10.13	1.39	9.47	10.27	10.82	0.72	13.31
	BTP 10 ind	103	8.16	0.60	7.85	8.22	8.57	5.21	9.22
slope	*BTP 30*	102	0.007	0.001	0.007	0.007	0.008	0.005	0.011
	BTP 10	139	0.004	0.001	0.003	0.004	0.004	0.003	0.006
	BTP 5	132	0.007	0.001	0.006	0.006	0.007	0.005	0.012
	BTP 3	153	0.009	0.002	0.008	0.009	0.010	0.006	0.020
	CTZ	142	0.014	0.003	0.011	0.013	0.016	0.008	0.029
	BTP 10 ind	82	0.012	0.002	0.011	0.012	0.013	0.010	0.027
DS	*BTP 30*	102	0.82	0.10	0.74	0.81	0.88	0.59	1.15
	BTP 10	139	0.43	0.08	0.38	0.41	0.47	0.31	0.71
	BTP 5	132	0.77	0.14	0.67	0.75	0.84	0.56	1.37
	BTP 3	153	1.27	0.25	1.12	1.24	1.41	0.79	2.28
	CTZ	142	7.49	1.89	6.00	7.16	8.90	4.22	11.75
	BTP 10 ind	82	1.22	0.13	1.14	1.20	1.30	0.99	1.84
DSS	*BTP 30*	102	0.0125	0.0024	0.0109	0.0119	0.0138	0.0090	0.0206
	BTP 10	139	0.0048	0.0012	0.0040	0.0046	0.0052	0.0030	0.0092
	BTP 5	128	0.0072	0.0024	0.0055	0.0067	0.0077	0.0042	0.0171
	BTP 3	153	0.0112	0.0059	0.0085	0.0097	0.0111	0.0058	0.0511
	CTZ	142	0.0195	0.0052	0.0156	0.0189	0.0230	0.0103	0.0385
	BTP 10 ind	82	0.0198	0.0032	0.0174	0.0199	0.0210	0.0153	0.0342
Market Quality Index 2	*BTP 30*	102	81.78	11.03	76.63	84.08	90.58	51.49	108.36
	BTP 10	139	259.67	37.30	233.04	261.51	286.76	164.10	353.91
	BTP 5	131	156.68	24.50	141.91	157.00	173.15	83.90	210.09
	BTP 3	153	116.88	16.08	105.80	117.38	129.88	69.77	147.85
	CTZ	142	86.40	20.12	70.44	82.26	101.37	42.15	136.66
	BTP 10 ind	82	55.17	7.83	50.76	53.63	58.25	24.69	74.51

Note: The measures are calculated weekly as mean steepness, mean slope, mean DS, mean DSS and mean market quality index 2 of the on-the-run securities. “p” is the p-th percentile of the distribution.

Table 06.13 – Comparison of Trading Measures across Securities

		# obs.	mean	sd	p25	p50	p75	min	max
trade size	*BTP 30*	102	3.49	0.34	3.29	3.50	3.75	2.65	4.32
	BTP 10	145	6.50	0.47	6.11	6.52	6.91	5.45	7.49
	BTP 5	129	6.37	0.78	6.10	6.47	6.84	3.25	8.19
	BTP 3	154	6.94	0.82	6.34	6.98	7.50	4.87	9.17
	CTZ	143	4.00	0.81	3.53	3.84	4.29	2.81	9.70
	BTP 10 ind	101	6.12	1.24	5.56	6.01	6.76	2.50	10.00
trading volume	*BTP 30*	102	72.42	55.034	36.80	63.93	91.71	6.24	379.61
	BTP 10	145	368.91	128.44	281.68	355.54	446.47	99.84	678.91
	BTP 5	129	163.27	100.81	91.74	139.24	220.49	33.34	657.63
	BTP 3	154	223.53	143.96	131.74	183.65	275.2	45.36	1086.43
	CTZ	143	169.77	98.26	106.18	146.62	200.06	37.74	564.97
	BTP 10 ind	101	62.97	44.770	30.232	54.22	79.09	5.08	238.05
trading frequency	*BTP 30*	102	19.90	16.38	10.06	16.66	24.94	1.67	134.47
	BTP 10	145	56.60	19.70	40.88	55.17	68.69	16.38	106.41
	BTP 5	129	26.39	18.29	13.83	21.63	36.95	5.40	125.95
	BTP 3	154	32.59	22.31	18.20	26.20	39.16	6.48	193
	CTZ	143	43.63	22.65	28.40	39.22	50.39	9.90	128.91
	BTP 10 ind	101	9.99	6.95	5.20	8.57	12.62	1	37.28
turnover ratio	*BTP 30*	102	0.55	0.44	0.27	0.44	0.61	0.04	2.63
	BTP 10	145	3.36	2.20	1.81	2.61	4.25	0.55	12.65
	BTP 5	126	1.44	1.43	0.62	0.93	1.88	0.19	11.36
	BTP 3	154	2.22	2.94	0.92	1.39	2.36	0.28	27.16
	CTZ	143	2.08	2.43	0.87	1.37	2.43	0.31	18.22
	BTP 10 ind	101	0.56	0.52	0.21	0.42	0.65	0.04	3.51
NTQ	*BTP 30*	101	0.003	0.004	0.001	0.003	0.004	-0.013	0.018
	BTP 10	138	0.001	0.001	0.000	0.001	0.001	-0.002	0.005
	BTP 5	123	0.002	0.003	0.001	0.002	0.003	-0.008	0.018
	BTP 3	152	0.002	0.002	0.001	0.002	0.004	-0.003	0.008
	CTZ	140	0.003	0.003	0.001	0.002	0.004	-0.005	0.013
	BTP 10 ind	73	0.007	0.013	0.003	0.006	0.011	-0.072	0.039
NTC	*BTP 30*	101	0.010	0.014	0.004	0.011	0.017	-0.045	0.064
	BTP 10	138	0.008	0.007	0.004	0.006	0.011	-0.011	0.031
	BTP 5	123	0.016	0.019	0.006	0.014	0.022	-0.056	0.104
	BTP 3	152	0.019	0.016	0.011	0.018	0.027	-0.026	0.059
	CTZ	140	0.014	0.011	0.007	0.013	0.020	-0.015	0.055
	BTP 10 ind	73	0.050	0.066	0.028	0.044	0.081	-0.179	0.244

Note: The measures are calculated weekly as mean trade size, mean daily trading volume, mean daily trading frequency and mean daily turnover ratio of the on-the-run securities. NTQ and NTC come from the regression, using the on-the-run sample, of five minute price changes on respectively the difference between buy and sell quantities and buy and sell number of trades as regressor. “p” is the p-th percentile of the distribution.

Table 06.14 Correlations of Market Condition Indicators across Securities

		BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
absolute price change	*BTP 30*	1					
	BTP 10	0.9732*	1				
	BTP 5	0.6644*	0.6963*	1			
	BTP 3	0.6961*	0.6473*	0.6527*	1		
	CTZ	0.6027*	0.4560*	0.5158*	0.7801*	1	
	BTP 10 ind	0.9527*	0.9565*	0.6455*	0.7595*	0.6986*	1
market particip.	*BTP 30*	1					
	BTP 10	0.4675*	1				
	BTP 5	0.4466*	0.4473*	1			
	BTP 3	0.6289*	0.6311*	0.5675*	1		
	CTZ	0.4167*	0.4019*	0.4765*	0.4396*	1	
	BTP 10 ind	0.5629*	0.4903*	0.5361*	0.5562*	0.3955*	1

Note: The table reports correlation coefficients for on-the-run securities. The measures are calculated weekly as mean absolute price change and mean market participants. The * indicates that the correlation coefficients are significant at the 5% level or better.

Table 06.15 Correlations of Order Book Measures across Securities

		BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
best spread	*BTP 30*	1					
	BTP 10	0.4930*	1				
	BTP 5	0.2902*	0.4755*	1			
	BTP 3	0.4140*	0.3791*	0.4547*	1		
	CTZ	-0.0518	-0.15	-0.3013*	-0.02	1	
	BTP 10 ind	0.0752	0.20	0.00	0.20	0.5577*	1
spread	*BTP 30*	1					
	BTP 10	0.3759*	1				
	BTP 5	0.3620*	0.3320*	1			
	BTP 3	0.2508*	0.2893*	0.4401*	1		
	CTZ	-0.2991*	0.14	-0.13	-0.09	1	
	BTP 10 ind	0.2036	0.5148*	0.04	0.12	0.2774*	1
best size	*BTP 30*	1					
	BTP 10	0.5030*	1				
	BTP 5	0.4477*	0.5100*	1			
	BTP 3	0.4022*	0.6468*	0.4946*	1		
	CTZ	0.2824*	0.5451*	0.2056*	0.3158*	1	
	BTP 10 ind	0.1874	0.1613	0.2253*	0.2052*	0.3023*	1
average quote size	*BTP 30*	1					
	BTP 10	0.2623*	1				
	BTP 5	0.2598*	0.4695*	1			
	BTP 3	0.3265*	0.6476*	0.4829*	1		
	CTZ	0.4634*	0.4545*	0.2926*	0.4930*	1	
	BTP 10 ind	0.1638	0.137	0.1864	0.2068*	0.3036*	1
steepness	*BTP 30*	1					
	BTP 10	0.3039*	1				
	BTP 5	0.3250*	0.1281	1			
	BTP 3	0.1581	0.2136*	0.2352*	1		
	CTZ	-0.1474	-0.1027	0.0049	-0.1116	1	
	BTP 10 ind	0.7543*	0.3812*	0.1457	-0.0613	0.0928	1
DS	*BTP 30*	1					
	BTP 10	0.183	1				
	BTP 5	0.3965*	0.5117*	1			
	BTP 3	0.3259*	0.2608*	0.2855*	1		
	CTZ	0.3596*	0.1332	0.3716*	0.3221*	1	
	BTP 10 ind	0.0138	0.4713*	0.4809*	0.21	0.3169*	1

Note: The table reports correlation coefficients for on-the-run securities. The measures are calculated weekly as mean absolute price change and mean market participants. The * indicates that the correlation coefficients are significant at the 5% level or better.

Table 06.16 Correlations of Trading Measures across Securities

		BTP 30	BTP 10	BTP 5	BTP 3	CTZ	BTP 10 ind
trading volume	*BTP 30*	1					
	BTP 10	0.1248	1				
	BTP 5	0.2376*	0.0603	1			
	BTP 3	0.0661	0.1674*	0.2249*	1		
	CTZ	0.0064	0.0791	-0.0359	0.1682*	1	
	BTP 10 ind	0.0558	-0.0529	0.2145*	0.0399	0.0191	1
NTQ	*BTP 30*	1					
	BTP 10	0.2121*	1				
	BTP 5	0.0584	0.0766	1			
	BTP 3	0.3481*	0.2496*	0.0158	1		
	CTZ	0.2756*	0.0069	0.1163	0.2727*	1	
	BTP 10 ind	0.0199	-0.0334	-0.0753	0.0604	0.114	1
NTC	*BTP 30*	1					
	BTP 10	0.2586*	1				
	BTP 5	0.0895	0.1428	1			
	BTP 3	0.4399*	0.2667*	0.0726	1		
	CTZ	0.2623*	0.1479	0.1591	0.3273*	1	
	BTP 10 ind	0.0959	0.0099	-0.1163	0.1429	0.1124	1

Note: The table reports correlation coefficients for on-the-run securities. The measures are calculated weekly as mean absolute price change and mean market participants. The * indicates that the correlation coefficients are significant at the 5% level or better.

7. Exploiting the Liquidity Measures: The Benchmark Analysis

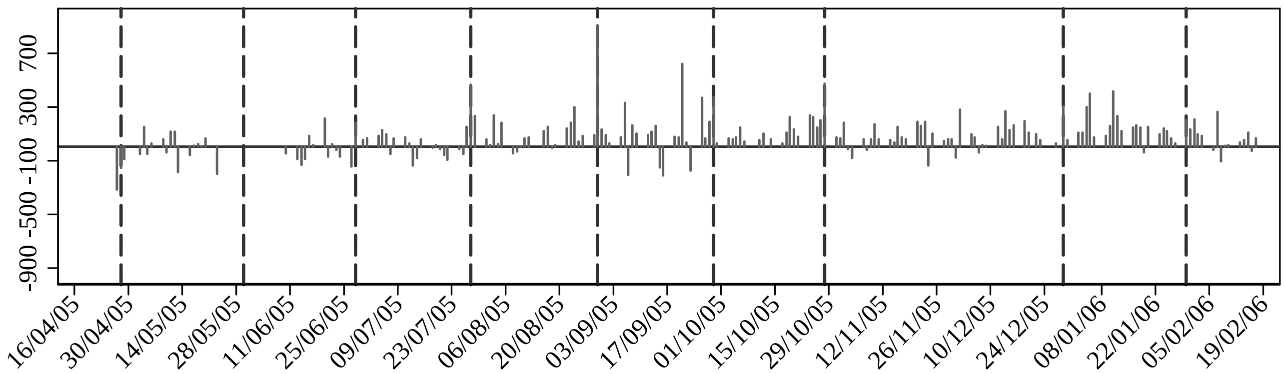
In this section we use the proxies for liquidity to try to understand when a new issued bond acquires the status of benchmark.

7.1. Benchmark Analysis

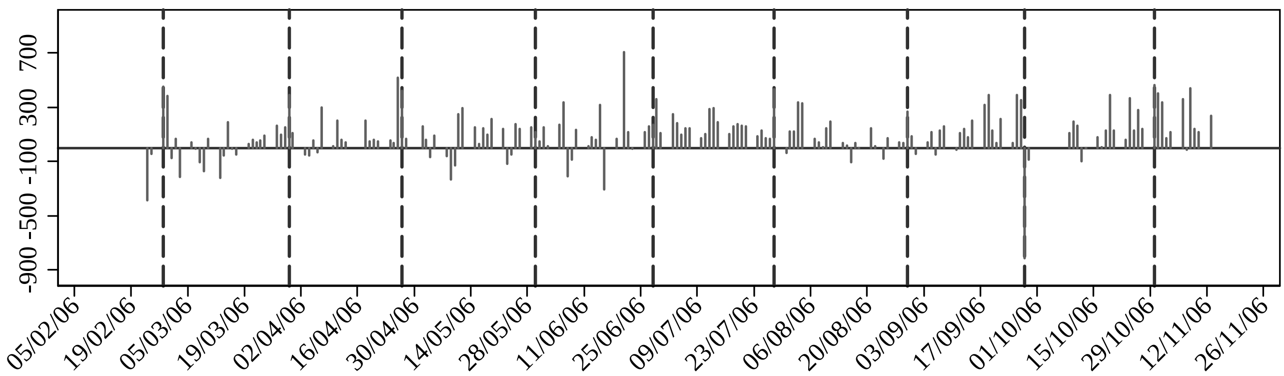
Both in the literature and in the industry the concept of benchmark security has been defined in many different ways: “Benchmark means the most liquid security, which is therefore most capable of providing a reference point for the market”; equivalently, “benchmark are issues whose yield are widely followed as macroeconomic indicators and used for pricing related securities” (CGFS, 1999); furthermore, benchmark “is the most recently issued security with a cumulative issue size over a certain threshold” (D’Souza et al., 2003). Other definitions state that “to define benchmark status one should focus directly on price discovery and regard the price discovery process as a purely empirical matter” (Dunne et al., 2002) or “a new bond becomes the benchmark issue when it has been traded more than the old benchmark for at least three consecutive days” (Alonso et al., 2004). Among the definitions adopted in the industry we have: “The eligible bond universe, to the status of benchmark, includes bonds issued within the previous two years with principal amount outstanding of € 5 billion at the date of the latest "tap" or auction. Issues of an outstanding volume of € 3 billion may be listed if the issuer commits to tap it to € 5 billion within 180 days of the auction and supported by at least 8 System Participants” (EuroMTS web site); or “also called on-the-run or current-coupon issue or bellwether issue, […] the benchmark issue is the most recently auctioned Treasury issues for each maturity” (Bloomberg web site).

The definition we are going to partially exploit in this analysis is the Alonso et al. (2004) one. In particular, we define as *benchmark a new issue that has been traded more than the old one for at least five consecutive days*. The day in which the security gains the status of benchmark is set equal to the first day of the series. This criterion is fairly general in that we do not assume a specific threshold on the size of the outstanding security. Hence we can compare directly different securities with a simple criterion. Moreover, it is more restrictive with respect to the Alonso et al. (2004) one because it requires a working week and not three days of higher trading volume for the new issue. In the following table we compare our definition with the EuroMTS one. In particular, the latter, in the Italian case, implies that a bond become benchmark as soon as it is issued. According to our definition a bond usually does not acquire the benchmark status as it is issued, but only with a certain delay. Figure 7.1 reports the difference in trading volume between on-the-run and off-the-run 10 year BTPs. The dashed vertical lines correspond to auction days. While in the upper panel the difference seems to be persistently positive after the third auction, in the lower panel this holds before the second auction takes place.

Figure 77.1 Trading Volume Differences



10Y 08/15 - 10Y 02/15



10Y 08/16 - 10Y 08/15

Note: The figure represents daily differences in the daily trading volume for the 10 year BTPs with maturity 02/15, 08/15 and 08/16. The differences are computed subtracting the trading volume of the off-the-run securities to the trading volume of the on-the-run securities. The differences are computed in millions of euros.

Table 7.1 shows the average number of trading days and the corresponding number of auctions needed for an on-the-run issue to become the benchmark for its segment according to our criterion. The index linked bond is excluded from our analysis because of the high number of days in which the bond is not traded. Referring to the central part of the table, the average difference of days is increasing in the original maturity of the bond and is in general less than 30 working days. If we work out the difference not in terms of days but of number of auctions and consequently of outstanding quantity, this difference is in general less than one auction. This means that the

Table 7.1 – Benchmark Analysis

		4 days				*5 days*				*6 days*				
Security	**ISIN code**	**Diff. (days)**	**mean day diff.**	**Num. auctions**	**Average outst.**	**Diff. (days)**	**mean day diff.**	**Num. auctions**	**Average outst.**	**Diff. (days)**	**mean day diff.**	**Num. auctions**	**Average outst.**	**note**
BTP 30	393465	5		1		5		1		132		3		
BTP 10	361838	12		1		12		1		20*		1		idem 6 - 11
	371991	36	22	2	5125	36	33	2	6437.5	72*	51	3	7625	
	384453	19	(10.1)	1	(1315)	63	(22.32)	3	(2164)	90*	(35.7)	4	(3479)	idem 6 - 7
	401958	21		1		21		1		21		1		idem 6 - 11
BTP 5	379959	7		1		7		1		7		1		
	387292	23	13	1	4375	23	27	1	5207.75	23	36	1	6832.75	
	402629	23	(12.39)	1	(750)	23	(19.21)	1	(1180)	59*	(24.68)	3	(3325)	idem 6 - 10
	411281	-2		0		53		2		53		2		idem 6 - 7
BTP 3	367423	11		1		11		1		94*		4		idem 6 - 7
	380485	0		1		0		1		0		1		idem 6 - 10
	387770	28	7	1	4200	35	14	2	4974	35	31	2	6314	
	400812	-3	(12.79)	0	(447)	-3	(17.02)	0	(1226)	-3	(39.07)	0	(3251)	idem 6 - 10
	408524	0		1		29		1		29		1		idem 6 - 9
CTZ	369706	16		1		16		1		16		1		idem 6 - 10
	383119	0	4	1	3250	0	8	1	3250	0	8	1	3250	idem 6 - 7
	392699	0	(8)	1	(500)	0	(8.96)	1	(500)	0	(8.96)	1	(500)	
	405105	0		1		15		1		15		1		

Note: Columns 3-7-11 report the difference in number of trading day between our criterion and the EuroMTS one. Columns 4-8-12 report for each maturity segment the averages of columns 3-7-11. Columns 5-9-13 report the difference in number of auctions, where 0 indicates the when-issue time period. Columns 6-10-14 report for each maturity segment the average outstanding in millions of euros. The last column reports a robustness check for the 6 days criterion. The* indicates that Difference (days) is influenced by the presence of a single day that is missing or of higher trading volume for the off-the-run security. Standard deviations are between brackets.

benchmark status is not acquired immediately, but usually we do not need to wait the first reopening, i.e. the second auction.

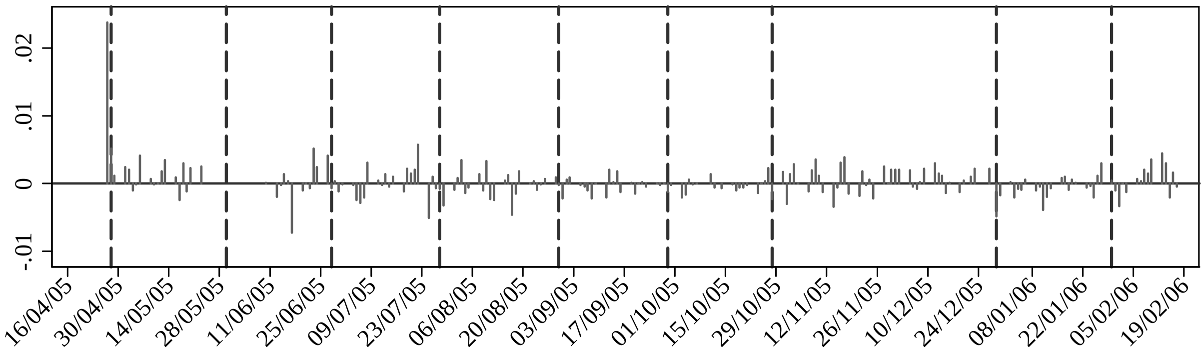
This evidence for the Italian securities seems to suggest that the issue sizes are well suited. Conversely, since in many cases the benchmark status is achieved just a few days before the second auction, it may be the case that the expectation of a new issue has a positive impact on trade. Columns 6-10 and 14 report for each segment the average outstanding. This is increasing in the maturity. In order to check the robustness of the "5 days" criterion, the table also displays the number of consecutive days with higher trading volume for the on-the-run securities using different criteria. In particular, we investigate "4 days" and "6 days" criteria. It turns out that tightening the criterion, i.e. increasing the number of days, delays the moment in which the security become benchmark. The number of auctions and the average outstanding increase also. The 10 year BTPs seem to be more sensible to variations in the criterion. However, for this security in 3 cases out of 4 the change from "5 days" to "6 days" criterion is affected by the presence of a single day of lower trading volume for the on-the-run issue with respect to the off-the-run. If we narrow the criterion further, in general we find no significant differences with the "6 days" criterion. The latter result confirms ex post the goodness of the choice of the "5 days" criterion.

7.2.The Quote Measures' Puzzle

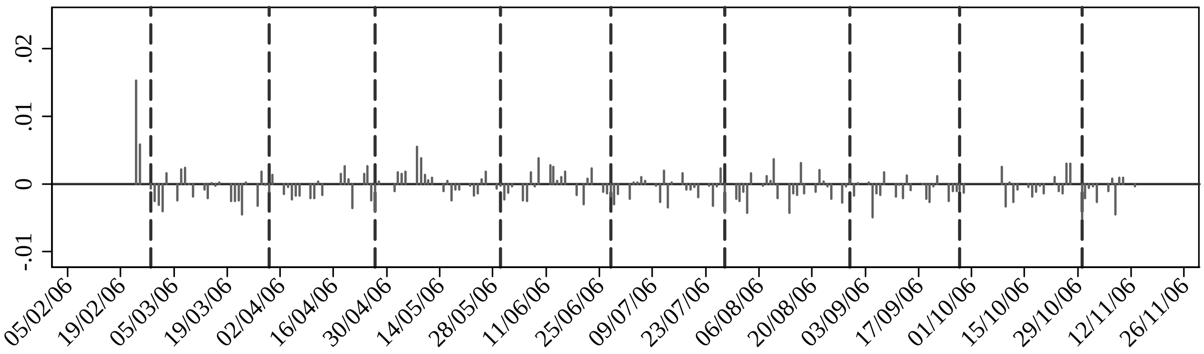
Given the results of the benchmark analysis we ask ourselves if we can extend this way of proceeding to variables other than the *trading volume*. As shown in the previous section, it turns out that, while, as expected, trading variables such as *trading frequency* and *turnover* show a clearly different pattern when we compare on-the-run and off-the-run securities, order book variables do not. In other words, we could expect that old securities trade at a higher spread and a lower depth, whatever measured, with respect to the new issues. Hence we should be able to identify when an on-the-run security achieves the status of benchmark in a consistent way with our previous analysis on trading data. This is not the case. In effect, the daily pattern of quoting variables is very erratic. This means that on some days the on-the-run securities trade at better conditions with respect to the off-the-run ones and on some others the contrary is true. We explained this occurrence by referring to market regulation. Market makers are subject both to the MTS Italy and to the Italian Treasury regulation. The former mainly concerns predetermined buckets of securities, the latter applies to all the traded securities. Since the Italian Treasury rules are somehow more binding, these are usually gone by and, as a result, there is no clear pattern in the quoting variables in the transition to the benchmark status[85]. Figure 7.2 reports the differences in the *best spread* by analogy with the previous figure. The pattern in the differences is erratic and, especially in the upper panel, the differences are often close to zero.

[85] As of April 2007, about half of the market makers are also Specialists and then they must obey to the Treasury regulation in order to maintain their status and participate to high remunerative operations.

Figure7.2 Best Spread Differences



10Y 08/15 - 10Y 02/15



10Y 08/16 - 10Y 08/15

Note: The figure plot daily differences in the best spread for the 10 year BTPs with maturity 02/15, 08/15 and 08/16. The differences are computed subtracting the best spread of the off-the-run securities to the best spread of the on-the-run securities. Best spreads are daily mean and they are computed in terms of prices.

This is consistent with our previous findings. In effect, at high frequency level, at a weekly level and in the comparative analysis we always found that order book data show small differences between on-the-run and off-the-run securities.

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Appendix A: Data Filtering

The raw dataset has to be filtered for two reasons: the presence of both negative bid-ask best spreads and outliers. Those drawbacks can be the consequence of some technical inconveniences in the procedure of data transfer from MTS to Italian Treasury. In the period 2004-2005 the number of records transferred to the Treasury is occasionally and marginally different with respect to the number of records in MTS data base. This generates cases of negative bid-ask spreads, which are inconsistent with the working of MTS platform. In effect, on MTS platform an ask proposal with a price smaller than the price of a bid proposal would be automatically executed. The same technical inconvenience could generate false outliers among the proposals. For false outlier we mean that bid (ask) quotes may seem to be too low (high) with respect to the other quotes in the same snapshot just because some records in between are missing. However, outliers could be the outcome of the behaviour of market makers as well.

First our filtering procedure eliminates all the snapshots where a negative best spread is present. Secondly, outliers are filtered out using thresholds on the gaps between prices within the same snapshot. For instance if the gap between the best bid price and the second best price is above the fixed threshold, this price and all the subsequent prices are filtered out. The thresholds are chosen in a way that they cut the sample around the 95% percentile. However, especially during the hours characterized by a lower trading activity, i.e. before 9.00am, after 4.00pm and around 1.00pm, the sample includes snapshots with only one bid and ask proposal. We call these “unique proposals”. Obviously we cannot apply the gap threshold in this case; hence we set a second threshold which is equal to the maximum spread we observe in the other snapshots. The maximum spread is the difference between the higher ask price and the lower bid price. The days characterized by problems in the working of the platform and by the suspension of the market making obligations are also excluded from the sample. The day the Citigroup-episode happened, i.e. August 2nd 2004, along with the day preceding and following that date are excluded from the sample as well. Tables A.1 and A.2 report respectively the effects of the filtering procedure on the original sample and the thresholds. The filtering procedure is worked out security by security.

Table A.1 Filtering procedure’s output

quotes	Obligations' suspension	Bestspread < 0	Gaps	Unique quotes	Other	total
BTP 30	1.13	0.004	2.81	0.04	0	3.99
BTP 10	0.51	0.16	5.19	0.02	0.005	5.89
BTP 5	1.28	0.06	4.85	0.01	0	6.20
BTP 3	0.80	0.04	3.58	0.01	0.18	4.61
BTP 10 ind	1.61	0.01	3.84	0.01	0.00	5.50
CTZ	0.74	0.10	2.33	0.02	0.00	3.19

contracts	Obligations' suspension	total
BTP 30	0.71	0.71
BTP 10	0.51	0.51
BTP 5	0.79	0.79
BTP 3	0.70	0.70
BTP 10 ind	4.14	4.14
CTZ	0.86	0.86

Note: The figures in the table are percentage. The breakdown of the sample is in Table 5.1.

Table A.2 Thresholds

	Gap	Max Spread
BTP 30	0.04	0.4
BTP 10	0.02	0.28
BTP 5	0.02	0.23
BTP 3	0.02	0.17
BTP10ind	0.06	0.42
CTZ	0.01	0.06

Note: The thresholds are measured in ticks.

Appendix B: Formulae

The signed variables represent mean values with respect to the *i*-th snapshot. For the sake of simplicity, the index *i* is usually ignored. $ask(bid)price_k$ is the *k*-th best quote on the ask(bid) side of the book. The number of proposals on the ask(bid) side of the book in the *i*-th snapshot are $n_{ask(bid)}$. Therefore, $k = 1, 2, \ldots, n_{ask(bid)}$. $ask(bid)qty_k$ is the quantity associated to the *k*-th best quote on the ask(bid) side of the book. The cumulative quantity from the first to the *k*-th position on the ask(bid) side of the book is given by $ask(bid)qtycumul_k \equiv \sum_{j=1}^{k} ask(bid)qty_j$. We divide the measures in two cathegories: Measures from quoting data and measures from trading data.

Measures from quoting data

- $best\ spread \equiv bestaskprice - bestbidprice$,
  where $bestask(bid)price \equiv ask(bid)price_1$;
- $spread \equiv \overline{askprice} - \overline{bidprice}$,
  where the bar indicates the average of the variable and the average is on all the quotes on the corresponding side of the book;
- $weighted\ spread \equiv \sum_{i=1}^{n_{ask}} askprice_i \cdot askweight_i - \sum_{i=1}^{n_{bid}} bidprice_i \cdot bidweight_i$,
  where the weights are $ask(bid)weight_i \equiv \dfrac{ask(bid)qty_i}{ask(bid)qtycumul_{n_{ask(bid)}}}$;
- $quote\ size \equiv \dfrac{bidquotesize + askquotesize}{2}$,
  where $ask(bid)quotesize \equiv ask(bid)qtycumul_{n_{ask(bid)}}$;
- $best\ size \equiv \dfrac{bidbestsize + askbestsize}{2}$,
  where $ask(bid)bestsize \equiv ask(bid)qty_1$;
- $second\ size \equiv \dfrac{bidscndsize + asksconsize}{2}$,
  where $ask(bid)sndsize \equiv ask(bid)qty_2$;
- $worst\ size \equiv \dfrac{bidworstsize + askworstsize}{2}$,

where $ask(bid)worstsize \equiv \sum_{j=3}^{n_{ask(bid)}} ask(bid)qty_j$;

- $average\ quote\ size \equiv \dfrac{\overline{askquotesize} + \overline{bidquotesize}}{2}$,

  where $\overline{ask(bid)quotesize} \equiv \dfrac{ask(bid)quotesize}{n_{ask(bid)}}$;

- $weighted\ depth \equiv \dfrac{bidwghtdepth + askwhgdepth}{2}$,

  where $bid(ask)wghtdepth \equiv \sum_{k=1}^{n_{bid(ask)}} \dfrac{bid(ask)qty_k}{1 + \left|\left(bestbid(ask)\,price - bid(ask)\,price_k\right)\right| * 100}$;

- $quote\ size\ per\ market\ participant \equiv \dfrac{quotesize}{marketparticipants}$,

  where *marketparticipants* measures the number of market makers who expose a double quote in each snapshot;

- $steepness \equiv \dfrac{bidsteepness + asksteepness}{2}$,

  where $bid(ask)steepness \equiv \dfrac{\left|bestbid(ask)\,price - worstbid(ask)\,price\right| * 100}{\dfrac{bestbid(ask)\,price + worstbid(ask)\,price}{2}}$;

- $slope \equiv \dfrac{bidslope + askslope}{2}$,

  where $bid(ask)slope \equiv \dfrac{\left|bestbid(ask)\,price - worstbid(ask)\,price\right| * 100}{bid(ask)quotesize - bid(ask)bestsize}$;

- $DS \equiv \dfrac{DBS + DAS}{2}$,

  where $DBS\ (DAS) \equiv \dfrac{\mathrm{cov}\left(bid(ask)\,price_k, bid(ask)qtycumul_k\right)}{\mathrm{var}(bid(ask)qtycumul_k)}$

- $Deepspread_l = askprice_{k_l^{ask}} - bidprice_{k_l^{bid}}$ for l = 2.5, 5, 7.5, 10, …

  where $k_l^{ask(bid)} = \min\left\{k \middle|\ ask(bid)qtycum_k \geq l\right\}$

- $DSS \equiv \dfrac{\mathrm{cov}\left(deepspread_m, m\right)}{\mathrm{var}(m)}$,

  where m is a multiple of 2.5 and indicates the cumulative quantities at which $deepspread_m \neq deepspread_{m-1}$;

- $market\ quality\ index = \dfrac{averagequotesize * midquote}{spread * 10000}$,

  where $midquote = \dfrac{\left(\overline{askprice_i} + \overline{bidprice_i}\right)}{2}$;

- $market\ quality\ index\ 2 = \dfrac{quotesize * midquote}{spread * 10000}$;

- $CRT(L) = \dfrac{2\left(\sum_{k=1}^{n_{ask}} I_k^{ask}\, askprice_k \cdot askqty_k - \sum_{k=1}^{n_{bid}} I_k^{bid}\, bidprice_k \cdot bidqty_k\right)}{L\left(bestaskprice + bestbidprice\right)}$,

  where

$$I_k^{ask(bid)} = \begin{cases} 1 & \text{if} \quad L > ask(bid)qtycumul_k \\ \dfrac{L - ask(bid)qtycumul_{k-1}}{ask(bid)qty_k} & \text{if} \quad ask(bid)qtycumul_{k-1} < L < ask(bid)qtycumul_k \\ 0 & \text{if} \quad \text{otherwise} \end{cases}$$

- *absolute price change* = $\left| midquote_i - midquote_{i-1} \right|$.

Measures from trading data

- *trading volume* = $\dfrac{(tradesize * contractprice)}{100}$
- *trading frequency* = #contracts concluded in the time interval
- *turnover ratio* = $\dfrac{tradingvolume}{outs\mathrm{tan}ding}$
- *net trading count = (#buy contracts − #sell contracts)*
- *net trading quantity* = $volumebuy - volumesell$

Appendix C: Tables

Table C.1 – Price Impact Regressions (prices) [1]

BTP 10 - on-the-run

	mod1	mod2	mod3	mod4
NTC	.00179633***		.00300138***	
NTQ		.00023451***	-.00017471**	
#buy				.00161982***
#sell				-.00198601***
_cons	-0.00013147	-0.00006703	-0.00016684	0.00023332
N	16493	16493	16493	16493
Adj R^2	0.0253	0.0218	0.0259	0.0254

BTP 10 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00242393***		.00525041***	
NTQ		.00029266***	-.0003819***	
#buy				.00237672***
#sell				-.00247228***
_cons	-.00082145***	-.00079843***	-.00084869***	-.00073654*
N	14787	14787	14787	14787
Adj R^2	0.0400	0.0335	0.0427	0.0399

BTP 5- on-the-run

	mod1	mod2	mod3	mod4
NTC	.00165581***		.00023421***	
NTQ		.00023421***	-0.00006379	
#buy				.00137219***
#sell				-.00196541***
_cons	-0.0002	-0.0001	-0.0002	0.0003
N	9110	9110	9110	9110
Adj R^2	0.0393	0.0335	0.0394	0.0401

BTP 5 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00114556***		.00199149***	
NTQ		.00014448***	-0.00012161	
#buy				.00139657***
#sell				-.00093947***
_cons	-0.0001	-0.0001	-0.0001	-0.0004
N	4795	4795	4795	4795
Adj R^2	0.0179	0.0148	0.0184	0.0180

BTP 3- on-the-run

	mod1	mod2	mod3	mod4
NTC	.00115837***		.00151003***	
NTQ		.00013797***	-0.00004927**	
#buy				.00101619***
#sell				-.00132328***
_cons	-0.00002	0.00004	-0.00004	0.00025
N	12307	12307	12307	12307
Adj R^2	0.0593	0.0484	0.0599	0.0599

BTP 3 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00104192***		.0011513***	
NTQ		.00012656***	-0.00001445	
#buy				.00107926***
#sell				-.00100637***
_cons	0.00002	0.00005	0.00002	-0.00004
N	5891	5891	5891	5891
Adj R^2	0.0607	0.0553	0.0606	0.0606

Table C.2 – Price Impact Regressions (prices) [2]

BTP 30- on-the-run

	mod1	mod2	mod3	mod4
NTC	.00645885***		.01177103***	
NTQ		.00147575***	-.00141641**	
#buy				.00470947***
#sell				-.00844888***
_cons	-.00188333*	-.00178245*	-.0019427*	0.0014
N	3527	3527	3527	3527
Adj R^2	0.0617	0.0491	0.0650	0.0649

BTP 30 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00573779***		.00658227*	
NTQ		.00140584***	-0.00022281	
#buy				.00557165***
#sell				-.00587237***
_cons	-.00337155*	-.0034665*	-.00337076*	-0.0031
N	1611	1611	1611	1611
Adj R^2	0.0461	0.0423	0.0455	0.0455

CTZ- on-the-run

	mod1	mod2	mod3	mod4
NTC	.00051526***		.00064672***	
NTQ		.00007902***	-.00003076***	
#buy				.00052232***
#sell				-.00050882***
_cons	-0.00007	-0.00007	-0.00007	-0.00008
N	14826	14826	14826	14826
Adj R^2	0.0370	0.0219	0.0379	0.0370

CTZ - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00034797***		.00043129***	
NTQ		.00005876***	-.00002016**	
#buy				.00035287***
#sell				-.00034342***
_cons	0.00004	0.00004	0.00004	0.00004
N	8072	8072	8072	8072
Adj R^2	0.0476	0.0306	0.0484	0.0475

BTP10ind on-the-run

	mod1	mod2	mod3	mod4
NTC	.00740692***		.00590956***	
NTQ		.00101923***	0.00022742	
#buy				.00763031***
#sell				-.00712548***
_cons	-.00193335*	-.00185117*	-.00193321*	-0.00239
N	1682	1682	1682	1682
Adj R^2	0.1969	0.1831	0.1975	0.1965

BTP10ind on-the-run

	mod1	mod2	mod3	mod4
NTC	.00498437***		.00431069*	
NTQ		.00074193***	0.00010938	
#buy				.00356282**
#sell				-.00593681***
_cons	-0.00245	-.00307077*	-0.00251	-0.00037
N	390	390	390	390
Adj R^2	0.1285	0.1193	0.1265	0.1295

Table C.3 – Price Impact Regressions (yields) [1]

BTP 10 - on-the-run

	mod1	mod2	mod4
NTC	.00556687***		
NTQ		.00073205***	
#buy			.00502615***
#sell			-.00614619***
_cons	-0.0002911	-0.00010347	0.00082848
N	15600	15600	15600
Adj R^2	0.0253	0.0222	0.0255

BTP 10 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00827773***		.01736769***	
NTQ		.00100229***	-.00122471***	
#buy				.00822709***
#sell				-.00833062***
_cons	-.00278909***	-.00271521***	-.00286959***	-.00269682*
N	13720	13720	13720	13720
Adj R^2	0.0381	0.0323	0.0403	0.0380

BTP 5- on-the-run

	mod1	mod2	mod4
NTC	.01211389***		
NTQ		.00170493***	
#buy			.01009039***
#sell			-.01458467***
_cons	-0.0015	-0.0006	0.0024
N	8792	8792	8792
Adj R^2	0.0390	0.0335	0.0398

BTP 5 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.01015879***		.01708408***	
NTQ		.00128409***	-0.00099393	
#buy				.01245334***
#sell				-.00830205***
_cons	-0.0006	-0.0004	-0.0008	-0.0037
N	4432	4432	4432	4432
Adj R^2	0.0183	0.0152	0.0187	0.0185

BTP 3- on-the-run

	mod1	mod2	mod4
NTC	.01545527***		
NTQ		.00182774***	
#buy			.01345838***
#sell			-.01783078***
_cons	0.00024	0.00112	.00411767*
N	11745	11745	11745
Adj R^2	0.0580	0.0471	0.0586

BTP 3 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.01711192***		.01953793***	
NTQ		.00207247***	-0.00032051	
#buy				.01762377***
#sell				-.01662439***
_cons	0.00045	0.00085	0.00038	-0.00038
N	5891	5891	5891	5891
Adj R^2	0.0618	0.0560	0.0617	0.0616

Table C.4 – Price Impact Regressions (yields) [2]

BTP 30- on-the-run

	mod1	mod2	mod4
NTC	.00929107***		
NTQ		.00212223***	
#buy			.00681039***
#sell			-.012113***
_cons	-.00277424*	-.00262903*	0.0019
N	3527	3527	3527
Adj R^2	0.0613	0.0488	0.0644

BTP 30 - off-the-run

	mod1	mod2	mod3	mod4
NTC	.00878009***		.01115693**	
NTQ		.00213565***	-0.00062768	
#buy				.00839777***
#sell				-.00909075***
_cons	-.0053145*	-.00543772*	-.00531986*	-0.0047
N	1543	1543	1543	1543
Adj R^2	0.0452	0.0408	0.0448	0.0446

CTZ- on-the-run

	mod1	mod2	mod4
NTC	.01080011***		
NTQ		.00164825***	
#buy			.01103121***
#sell			-.01059124***
_cons	-0.00093	-0.00097	-0.00136
N	14542	14542	14542
Adj R^2	0.0387	0.0227	0.0386

CTZ - off-the-run

	mod1	mod2	mod3	mod4
NTC	.01126714***		.01289487***	
NTQ		.0019654***	-0.00039378	
#buy				.01145072***
#sell				-.01109639***
_cons	0.00132	0.00131	0.00133	0.00099
N	8065	8065	8065	8065
Adj R^2	0.0534	0.0367	0.0536	0.0533

BTP10ind on-the-run

	mod1	mod2	mod4
NTC	.05511498***		
NTQ		.00745932***	
#buy			.05081192***
#sell			-.05987435***
_cons	-.01929499**	-.01722019*	-0.01106
N	1301	1301	1301
Adj R^2	0.1988	0.1761	0.1989

BTP10ind on-the-run

	mod1	mod2	mod3	mod4
NTC	.03867193***		.03309337*	
NTQ		.00576182***	0.00090572	
#buy				.02791238**
#sell				-.04588085***
_cons	-0.01789	-.02269709*	-0.01836	-0.00213
N	390	390	390	390
Adj R^2	0.1308	0.1217	0.1288	0.1317